5-1903

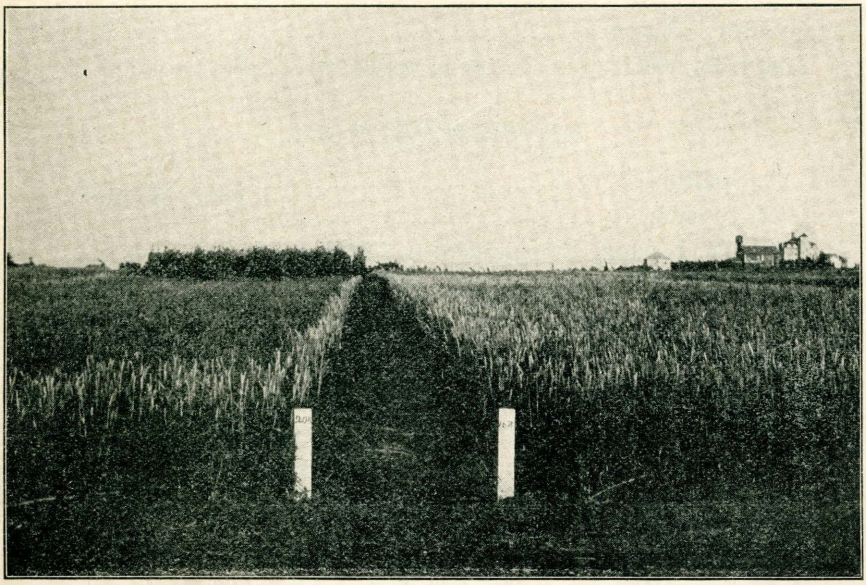
Crop Rotation for South Dakota

E.C. Chilcott
South Dakota Agricultural College

Bulletin 79 May, 1903

South Dakota Agricultural College

EXPERIMENT STATION



Wheat after Wheat
Yield, 3.16 Bushels

Wheat after Fallow
Yield, 18.00 Bushels

CROP ROTATION

— FOR —

SOUTH DAKOTA

E. C. CHILCOTT

Department of Agriculture

BROOKINGS, SOUTH DAKOTA

ABERDEEN, S. D.
NEWS PRINTING CO.
1903

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Any farmer of the state can have the Bulletins of this Station free upon application to the Director.

NOTE—All the cuts in this Bulletin are from photographs taken during the very unfavorable season of 1900, and are intended to show the beneficial effects of a proper rotation of crops. See page 51.

CROP ROTATION FOR SOUTH DAKOTA

E. C. Chilcott, Agriculturist

INTRODUCTION

That some definite system of crop rotation must be adopted by the farmers of this state before they can hope to obtain the best returns from their farms is a proposition that admits of no denial. That no rotation can be devised that will be equally suitable for all the farms of the state is also an unquestionable fact. Each individual farmer will have to work out the details of a rotation for his particular farm. But it is the belief of the writer that much can be done by the Experiment Station in determining some of the general principles involved in the various problems that farmers will have to solve in this connection. It was with this purpose in mind that the experiments outlined in this Bulletin were begun in the spring of 1897 and have been carried on down to the present time. It is to be hoped that the work now so well under way may be continued without interruption for a long term of years, as its value will steadily increase with each succeeding year of its continuance. Six years' records are now on hand, but it is doubtful whether any very definite conclusions can be drawn from the results of so limited a series of experiments. The main purpose of this Bulletin is therefore to call the attention of the farmers of the state to the importance of the problems involved and the methods adopted at this Station to solve them. If we succeed in arousing sufficient interest in the subject among a few of the most intelligent and progressive farmers, so that they will aid us by co-operation, criticism or advice, we will have accomplished our purpose in the publication of this Bulletin and will wait until longer experience and more decisive results warrant us in making more definite and positive statements.

It will be well for us at the very outset to briefly consider some of the most important factors involved in the problems before us.

Crop rotation is a subject that has engaged the attention and study of the very best talent among agricultural investigators and practical farmers for a great length of time in all of the older parts of the world where agriculture has reached its highest state of development. If we could appropriate the results of their investigations and experience we would find a rich store-house of facts in the literature of the subject, particularly the records of the long line of experiments carried on by Sir J. B. Lawes and Sir J. H. Gilbert at Rothemsted, England. It would be almost impossible to overestimate the value to the whole civilized world of the work of these investigators, nor do we undervalue the work done by the army of agricultural investigators connected with the United States Department of Agriculture and the various state Experiment Stations. But, unfortunately, in the matter of crop rotation their results have a value to us in only a very broad and general way. This is essentially a local problem and can be solved only under local conditions. Nor is this matter of locality confined to a comparison of this state as a whole with other states or countries. Each of the several sections of the state has its local conditions, peculiar to itself, and in the ultimate analysis every farm will have its peculiar conditions, and every farmer his individual problems to solve.

Among the most important considerations that should enter into any discussion of crop rotation must be the following:

1. Climatic conditions; precipitation, annual and seasonal; temperature, annual and seasonal; length of growing season, winds, frosts, etc.

2. Soil conditions; chemical, and physical or mechanical; effects of tillage upon soil water; effects of the growth of various crops upon the crop-producing powers of the soil, either by depleting the soil of its fertility, or changing its mechanical condition.

3. The relation that various crops bear to each other when grown in succession.

4. Effects of the application of manure in various ways and at different times.

5. Effects of summer fallowing.

6. Effects of plowing under green crops for manure.

The above are of a sufficiently general nature that any light that may be thrown upon them by the results obtained at this station will be of value to the farmers of a larger part, if not the whole of the state. We will therefore confine our discussion largely to these problems and conditions and their inter-relations; and will leave the more local and changeable ones, such as the relative quantities of each crop to be grown, the amount of stock to be kept, etc., etc., to the individual farmers. It is believed that some one of the rotations suggested in the following pages will be found suitable to almost any local conditions that are likely to exist in this state.

In the latter part of this Bulletin will be found a description of an experiment upon the application of manure to wheat which was conducted in 1897, 1898 and 1899, the results of which have not been published. It is believed that a careful study of these experiments in connection with those on crop rotation will help to bring about a more thorough understanding of some of the problems connected with farming in this state.

The writer is fully aware of the fact that there is a demand among a large class of people for the **sensational,** even in scientific publications, a demand that is, we are sorry to say, catered to by some writers connected with the Experiment Stations, but to a far greater extent by contributors to agricultural papers. But by far the worst offenders in this respect are the self-styled investigators who claim to have made some wonderful discovery that is destined to speedily revolutionize the agricultural methods of this country. This state has done its share in producing this class of adventurers, and it is probable that its resources in this direction are not yet exhausted. It is possible that these people do some good by causing people to try some experiments for themselves that they would not otherwise undertake. But, on the whole, their influence is bad, for they hold out hopes that are never realized and often induce people who can ill afford it to go to considerable expense in adopting a "system" that will not work in practice. Another bad effect is the discredit that they cast upon the honest, truth-seeking investigator whose only object is to learn as much as possible of nature's laws and give the people the benefit of his investigations.

The reader will find nothing sensational nor revolutionary in the following pages, but rather the carefully observed and recorded results of practical experience. The general results are in accord with those of the practical farmers of the state. But the facts are of such a nature and bear such a relation to each other that they are of far more value than those in the possession of any practical farmer, no matter how wide his experience or how close his observation. Each rotation is represented on our experimental grounds by a miniature farm, upon which all the farming operations necessary for the raising of the several crops are carried on, just as on a larger farm. Every crop is sown, tended and harvested by itself, and a careful record is kept, not only of the yield of grain and straw, but also of the general character of the growth and the produce. We, therefore, have the practical experience carefully recorded of conducting twenty-two separate farms under different systems of rotation and all located upon soil of uniform character, thus making the results obtained upon each strictly comparable with all the others.

Upon these miniature farms one hundred and eighty crops of wheat have been raised. Of these thirty-six were raised after corn, thirty-six after wheat, twenty-four after oats, twenty-four after fallow, twenty-four after millet, twenty-four after peas, six after root crops and six after vetch.

Sixty-six crops of corn, forty-eight of oats, thirty of barley, twenty-four each of peas and millet, twelve of flax and six each of roots and vetch have been raised, and twenty-four summer fallows have been made.

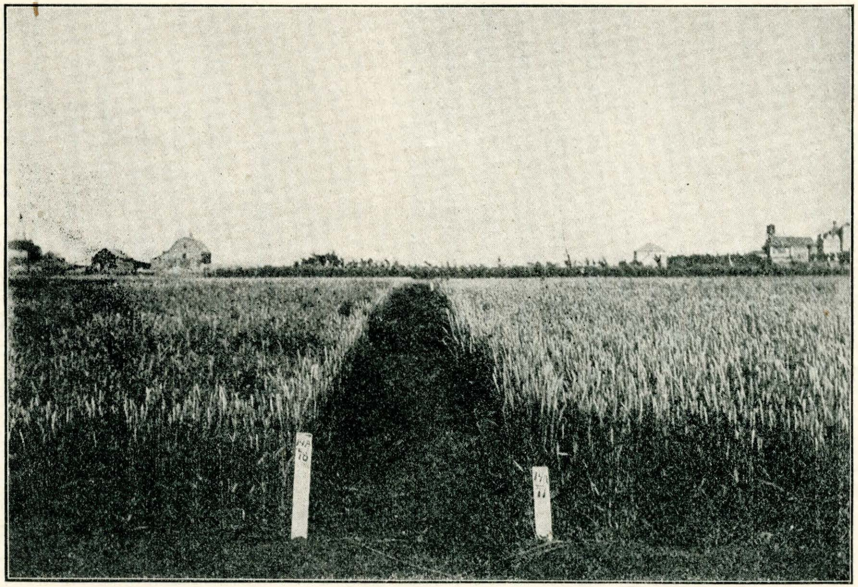
Many more details might be given, but enough has been said to show that this work has given us a store of practical experience along these lines greater than could possibly enter into the life of any single practical farmer. Not only have we had the benefit of this experience, but what is of far greater importance, we have an accurate record of that experience. A careful study of the following pages will enable the farmers of the state to profit by this experience.

It will be readily seen that an enormous amount of very careful, painstaking work has been involved in this experiment. The work has, much of it, necessarily, been done by my assistants and the employes of the Station, and to them is largely due the credit of the work. Among these, John S. Cole, a student of the College and now a special agent of the Department of Agriculture, and Wm. West, farm foreman, deserve special mention.

OUTLINE OF EXPERIMENTS

In the spring of 1897 a field containing about eight and one-half acres was selected for the experiments in crop rotation. The soil was known to be of very uniform character throughout, not only from careful examination and analysis, but from the uniform character of the crops it had raised for a number of years previous to the beginning of the experiment. It is not definitely known just how long it had been under cultivation, but certainly not less than fifteen years. Wheat, oats and corn had been the principal crops raised. Very little manure had been applied.

The soil is an unmodified glacial drift known to geologists as the Iowa sheet, and consists of clay, sand and boulders, with a large percentage of lime, particularly in the subsoil, as will be seen from the chemical analysis below. It is what



Wheat after Wheat
Yield, 4.33 Bushels

Wheat after Fallow
Yield, 15.00 Bushels

would generally be called a sandy loam and would be considered a good corn soil for this locality, but rather too sandy for a first class wheat soil.

We here give in tabular form a mechanical and a chemical analysis of the soil:

Table I—Chemical Analysis of Soil from Station Plats

J. H. Shepard, Chemist

CHEMICAL CONSTITUENTS	Surface Soil per cent	Intermediate Soil per cent	Sub-soil per cent
Insoluble matter (SiO_2)	81.5310	81.8800	76.9345
Potash (K_2O)	.3523	.5989	.2124
Soda (Na_2O)	.4311	.7796	.5645
Lime (Ca O)	.9325	2.9945	6.7750
Magnesia (MgO)	.7727	1.0565	1.7567
Ferric oxide (Fe_2O_3)	2.9342	3.3130	2.9528
Alumina (Al_2O_3)	4.0258	4.9251	4.7742
Phosphorus pentoxide (P_2O_5)	.1600	.1919	.2430
Sulphur trioxide (SO_3)	.1484	.1156	.1047
Organic matter	8.3600	4.1150	5.3130
Carbon dioxide (CO_2) and loss	.3520	.0299	.3692
Total	100.0000	100.0000	100.0000

Table II—Mechanical Analysis of Soil from Station Plats

Number	DESIGNATION OF PARTICLES	Diameter in mm.	Surface Soil per cent	Intermediate Soil per cent	Sub-soil per cent
1	Coarse grits	1-3	1.54	5.18	3.91
2	Fine grits	.5-1	6.88	2.82	2.70
3	Coarse sand	.50	7.36	8.57	5.28
4	Medium sand	.30	.35	2.38	2.60
5	Fine sand	.16	4.64	9.81	12.89
6	Finest sand	.12	7.36	5.47	4.07
7	Coarse silt	.072	4.87	5.09	5.88
8	Large silt	.047	6.06	5.99	9.04
9	Medium silt	.036	5.68	4.46	3.08
10	Fine silt	.025	10.53	3.58	7.29
11	Finest silt, separated by elutriator	.016	18.08	17.42	16.74
12	Finest silt, separated by sedimentation	.010	.39	1.62	2.09
13	Clay	.0001	13.39	20.84	16.11
	Organic matter	....	9.64	4.95	7.66
	Total	....	96.77	98.18	99.34
	Water free sample	....	100	100	100
	Loss	....	3.23	1.82	.66

The character of the soil is very similar to that found over a large portion of the state east of the Missouri River.

Water is found in this vicinity in veins of glacial gravel, at a depth of about twenty-five to thirty feet. The formation from the surface down to this depth is a very compact glacial clay, such as is described in the table of mechanical analysis under the head of subsoil.

The surface of the field is nearly level, entirely free from depressions, "draws," drains, or peculiarities of any kind. It slopes very gently toward the north, thus preventing water from standing upon any part of it at any time. It is so located that it does not receive the washings from adjacent fields to any appreciable extent.

This field was divided into seventy one-tenth acre plats, each two chains long and fifty links wide. There are five series, each containing fourteen plats. The series are separated by driveways, each twenty-five links wide, and the plats by alleys five links wide. The driveways are kept graded, slightly higher in the center than near the sides next the plats, thus forming two shallow surface drains or gutters which carry off any excess of surface water. The alleys are kept cultivated and free from all vegetation during the growing season. The corners of each plat are permanently marked by pieces of water pipe driven deeply in the ground, with the upper ends just at the surface. During the growing season wooden stakes, painted and properly labeled, are placed at each corner.

All the plats are plowed in the fall, crosswise by series, care being taken not to disturb the iron corner posts. In seeding the plats to small grain each plat is sown separately with a common grain drill, care being taken to see that the seeding extends slightly beyond the limits of each plat. As soon as the grain is well up each plat is carefully trimmed to exact dimensions with a hoe and garden line. Like precautions are taken with other crops, in order that each plat shall contain exactly one-tenth of an acre of crop. Each grain plat is harvested and threshed separately, a threshing machine of special construction being provided for this purpose. The product of each plat is weighed before threshing and the grain is kept separate and also carefully weighed. Other crops are treated in like manner. When certain crops are to be fed off on the land they are fenced, and hogs, sheep or cattle are kept upon them until the crop is consumed. A record is kept of the length of time and the quantity of stock required to consume the product of the plats, and also of the loss or gain of the stock in weight.

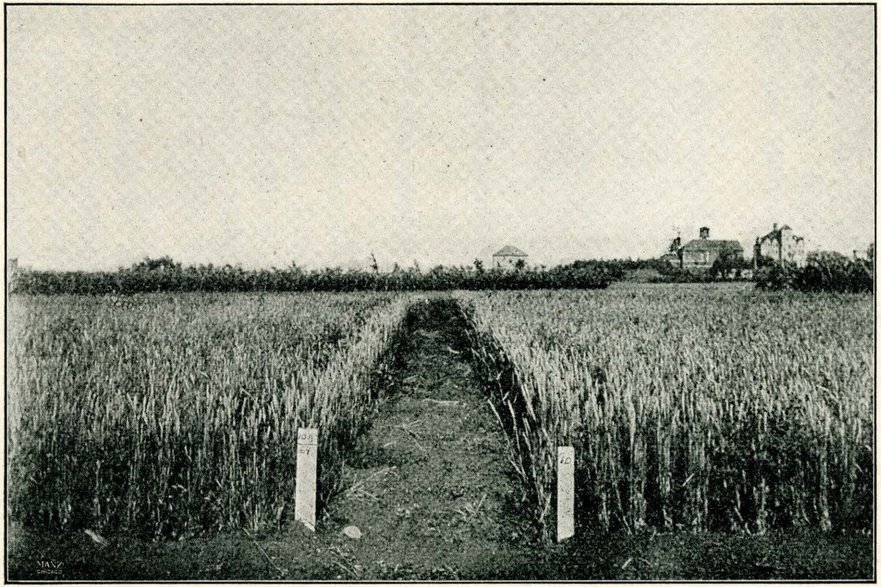
The plats are visited daily during the growing season and careful notes taken of any peculiarity of growth, attacks of insects or disease, effects of climatic conditions, etc., etc.

The same variety is grown upon all plats of each of the different crops. The seeding of all the plats of each kind of crop is done upon the same day, and, as nearly as possible, under exactly identical conditions. Each cultivated crop receives the same culture on all the plats.

All summer fallowed plats are plowed once in July and again in the fall.

Wherever manure is applied to wheat it is at the rate of twenty tons to the acre of well rotted, mixed barnyard manure, applied as a mulch immediately after seeding. To the corn ground, when manured, it is applied at the same rate and of the same kind, in the spring before planting and thoroughly disced in.

It will be noticed that no grass enters into any of the original twenty-two systems of rotation already mentioned. The reason for this omission was not that we did not consider such a crop desirable in a rotation, but that at the time of inaugurating these experiments we did not feel enough confidence in being able to secure a catch of grass every year to warrant us in attempting it, fearing that a failure to secure a catch would complicate the problem and obscure the results. We have now become convinced that Bromus inermis can be safely relied upon as a meadow or pasture grass and, therefore, we added two more rotations in the spring of 1902. One



Wheat after Oats
Yield, 4.33 Bushels

Wheat after Corn
Yield, 14.50 Bushels

of these is a six year, and the other a five year rotation, and each contains Brome grass, which is to be sown with a crop of wheat and to be cut for two seasons and then plowed under. These eleven plats are adjacent to the original ones and the conditions and soil are in every way like them. It is believed that this is a very valuable addition to the experiment, but of course it will be several years before any reliable results can be obtained from them.

A complete meteorological record has been kept and the mean temperature and precipitation for the growing months and the year are here given:

METEOROLOGICAL TABLES

Table III—Temperature

	April	May	June	July	August	Seasonal 5 Months	Annual
1897	44.1	56.1	63.1	71.2	63.6	59.6	41.7
1898	45.6	54.5	66.3	70.4	69.6	61.3	43.6
1899	43.8	55.2	64.8	69.2	69.4	60.5	41.6
1900	50.2	60.0	66.1	68.2	74.0	63.7	44.2
1901	47.1	57.0	65.9	76.2	70.4	63.3	44.0
1902	42.0	58.2	60.2	69.6	65.1	59.0	42.3
Normals	43.7	55.6	65.1	70.2	67.6		42.5

Seasonal average for six years, 61.2°.

Table IV—Precipitation

	April	May	June	July	August	Seasonal 5 Months	Annual
1897	2.45	.83	3.86	4.32	3.59	15.05	22.94
1898	.88	5.15	1.94	1.56	2.78	12.31	16.65
1899	3.36	3.38	5.42	.73	3.25	16.14	20.23
1900	1.68	1.23	1.62	5.10	4.00	13.63	24.56
1901	1.40	1.80	4.51	1.66	2.94	12.31	19.76
1902	1.60	2.66	3.17	2.75	5.30	15.48	21.83
Normals	2.33	2.72	3.43	2.29	2.53		19.01

Seasonal average for six years, 14.15 inches.

THE ROTATIONS

It is believed that the following tabular arrangement will give a clear idea of the rotations. Each rotation is given a number, by which it is known. Each rotation includes as many plats as there are years in the rotation, and each plat is known by a letter. By this means any particular plat can be easily identified by the number of the rotation and the letter of the plat. Thus 6-B would indicate the second plat in the sixth rotation; 5-C the third plat in the fifth, etc., etc.

It is not to be understood that these rotations are all recommended as the best that could be devised where the same crops are to be grown. The plan was to adopt rotations of various lengths, including the principal crops raised in the state, and then to allow the results to determine which combinations were most desirable. It is believed that we can already see where a different arrangement of the crops in relation to each other would be beneficial, and it is confidently believed that future results will throw still further light upon the subject.

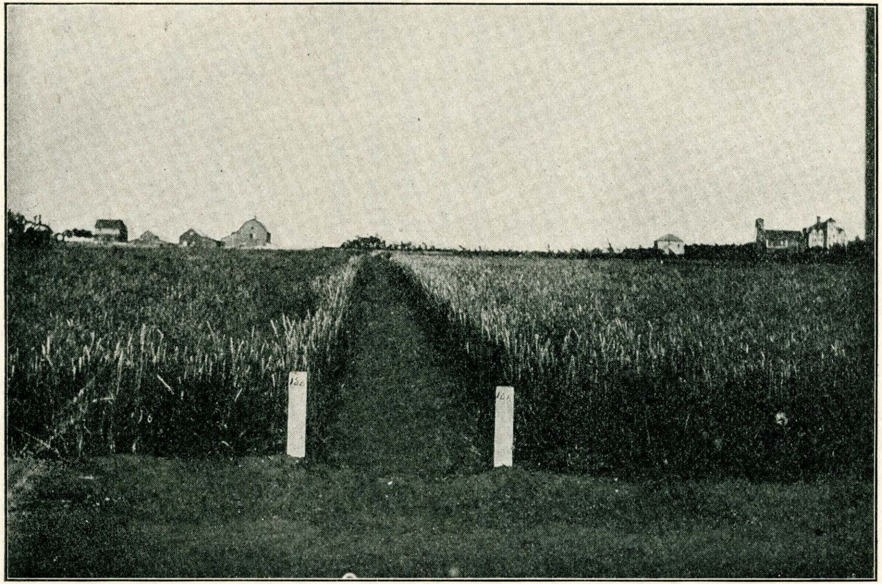
It will be noticed that wheat enters into every rotation and that in several it occurs twice. This is not because we believe that wheat should be grown on every farm, but because we consider it desirable that some one crop should enter into them all for the purpose of comparison. Wheat is, and will long remain, one of the most generally raised crops in this state, and it possesses some advantages over any other for purposes of comparison.

The record of the produce of all crops has been carefully kept, but it has been considered desirable to give only those of wheat, oats and barley. And in computing the averages for each rotation the yields of either four or five years are included for wheat, four for oats and three for barley. We did not consider it desirable to include those for the first year, 1897, owing to the fact that we have found that the effect of the immediately preceding crop is one of the most, if not the most, important factor in determining the yield, and as the crop of 1896 was the same for all the plats, the yields for 1897 were quite similar. No record was obtained for the crop of 1899 for any of the oat or barley plats, nor for the wheat in rotations 1 to 10, inclusive, on account of a tornado that damaged the grain while in the shock and mixed it so badly that it was impossible to separate it. The yield for that year was a very good one, while that for 1900, which is included in the estimate, was the poorest for many years, which accounts for the low averages for the four years, 1898, 1900, 1901, 1902. The yield of barley for 1900 is not included, as it was a total failure. This does not affect the value of these figures for comparison, but they should not be taken as a fair average for this locality.

It will be noticed that when wheat occurs twice in any rotation, one is designated as wheat-1 and the other as wheat-2, and the average yield of each is given. As these two crops have been raised under identically the same conditions, except in the matter of the preceding crop, a comparison of the yields of the two will serve to throw much light upon the effects of the immediately preceding crop. This matter will be discussed at greater length when we come to a consideration of the several rotations.

The figures at the left hand give the year, and by tracing across horizontally from any of these figures it can be readily seen just what crop was raised on each of the plats for that year, under the appropriate heading for the plat.

As has already been stated, it seems necessary to use the yield of wheat on each rotation almost entirely as a standard by which to judge of the value of the rotation. At first thought it might seem that the total dry matter produced by all the crops entering into the rotation would be a better standard; but if this were done it would be necessary to either assume that all the dry matter was of equal value, or to adopt some arbitrary standard of value for each; neither of these methods would be at all satisfactory. Then again some of the crops are not harvested, but are either fed off or plowed



Wheat after Wheat
Yield, 3.33 Bushels

Wheat after Corn
Yield, 12.33 Bushels

under. In these cases we would be forced to resort to an estimate of the yield, which would be pure guess-work. And again, there are certain crops, like corn, that are very difficult to raise in small plats in such a way as to obtain yields that are comparable with the crop raised in large fields. Gophers often work along the edges of the plats and make anything like a perfect stand impossible, and in so small a plat as one-tenth of an acre the loss from this source is very important, while in a large field it would not be noticeable. The wind also often does much damage to a small plat, when it would not materially affect a large field. None of these objections can be urged against the wheat crop, as the growth is almost invariably enough better along the edges of the plat to offset any loss that might occur from exposure.

We shall, therefore, use the wheat yield as the standard in our discussions, recognizing that while it is not an ideal standard, it is probably the safest one that can be adopted. As the opinions expressed are purely tentative and are calculated rather to bring out criticism and discussion than to answer controverted questions, this standard will serve to bring out certain facts as well as though it were a more reliable one. What we have given as facts we stand ready to vouch for, but we reserve the right to modify our opinions whenever new facts bearing upon the subject are established. And we also recognize the right of any one to attack our opinions, and we invite criticism. An eminent scientist once told the writer that he considered the most stimulating writers those who were continually advancing theories with which he did not agree, as it set him to looking up the foundation for his own opinions. It may be that the suggestions herein made will serve the same purpose.

A reference to Table V will show that the average yield of all wheat plats for the five years is: Straw, 2,292 pounds; grain, 14.47 bushels per acre, and that the ratio of grain to straw is 1:2.65. This, then, shall be the standard by which to judge the rotations.

Table VI shows the average yield of oats to be: Straw, 2,231 pounds, and grain 43.64 bushels per acre, and the ratio of straw to grain, 1 :1.58. And of barley, straw, 1,963 pounds, and grain 37.25 bushels per acre, and a ratio of straw to grain of 1 :1.15.

Five Year Rotation—No. 1

Plats	A	B	C	D	E
1897....	Flax	Barley	Millet	Wheat	Corn
1898....	Barley	Millet	Wheat	Corn	Flax
1899....	Millet	Wheat	Corn	Flax	Barley
1900....	Wheat	Corn	Flax	Barley	Millet
1901....	Corn	Flax	Barley	Millet	Wheat
1902....	Flax	Barley	Millet	Wheat	Corn

	Straw lbs.	Grain bu.
Average yield per acre of wheat for five years	2498	15.25
Average yield per acre of barley for four years	2075	40.20

Five Year Rotation—No. 2

Plats	A	B	C	D	E
1897....	Wheat-1	Oats	Peas (fed)	Wheat-2	Roots
1898....	Oats	Peas (fed)	Wheat-2	Roots	Wheat-1
1899....	Peas (fed)	Wheat-2	Roots	Wheat-1	Oats
1900....	Wheat-2	Roots	Wheat-1	Oats	Peas (fed)
1901....	Roots	Wheat-1	Oats	Peas (fed)	Wheat-2
1902....	Wheat-1	Oats	Peas (fed)	Wheat-2	Roots

	Straw lbs.	Grain bu.
Average yield per acre of wheat-1 for four years	2315	16.41
Average yield per acre of wheat-2 for four years	2228	15.16
Average yield per acre of oats for four years	2495	44.60

Five Year Rotation—No. 3

Plats	A	B	C	D	E
1897....	Oats	Wheat-1	Fallow	Wheat-2	Corn
1898....	Wheat-1	Fallow	Wheat-2	Corn	Oats
1899....	Fallow	Wheat-2	Corn	Oats	Wheat-1
1900....	Wheat-2	Corn	Oats	Wheat-1	Fallow
1901....	Corn	Oats	Wheat-1	Fallow	Wheat-2
1902....	Oats	Wheat-1	Fallow	Wheat-2	Corn

	Straw lbs.	Grain bu.
Average yield per acre of wheat-1 for four years	2103	13.04
Average yield per acre of wheat-2 for four years	2378	15.40
Average yield per acre of oats for four years	2228	48.75

Five Year Rotation—No. 4

Plats	A	B	C	D	E
1897....	Wheat-1	Barley	Peas (plowed)	Wheat-2	Corn
1898....	Barley	Peas (plowed)	Wheat-2	Corn	Wheat-1
1899....	Peas (plowed)	Wheat-2	Corn	Wheat-1	Barley
1900....	Wheat-2	Corn	Wheat-1	Barley	Peas (plowed)
1901....	Corn	Wheat-1	Barley	Peas (plowed)	Wheat-2
1902....	Wheat-1	Barley	Peas (plowed)	Wheat-2	Corn

	Straw lbs.	Grain bu.
Average yield per acre of wheat-1 for four years	2498	17.70
Average yield per acre of wheat-2 for four years	2603	16.12
Average yield per acre of barley for four years	1983	35.75

Five Year Rotation—No. 5

Plats	A	B	C	D	E
1897....	Wheat	Oats	Corn	Flax	Millet (fed)
1898....	Oats	Corn	Flax	Millet (fed)	Wheat
1899....	Corn	Flax	Millet (fed)	Wheat	Oats
1900....	Flax	Millet (fed)	Wheat	Oats	Corn
1901....	Millet (fed)	Wheat	Oats	Corn	Flax
1902....	Wheat	Oats	Corn	Flax	Millet (fed)

	Straw lbs.	Grain bu.
Average yield per acre of wheat for four years....................	2450	15.29
Average yield per acre of oats for four years......................	2460	41.48

Five Year Rotation—No. 6

Plats	A	B	C	D	E
1897....	Wheat-1	Barley	Peas (cut)	Wheat-2	Corn (fed)
1898....	Barley	Peas (cut)	Wheat-2	Corn (fed)	Wheat-1
1899....	Peas (cut)	Wheat-2	Corn (fed)	Wheat-1	Barley
1900....	Wheat-2	Corn (fed)	Wheat-1	Barley	Peas (cut)
1901....	Corn (fed)	Wheat-1	Barley	Peas (cut)	Wheat-2
1902....	Wheat-1	Barley	Peas (cut)	Wheat-2	Corn (fed)

	Straw lbs.	Grain bu.
Average yield per acre of wheat-1 for four years..................	2392	16.10
Average yield per acre of wheat-2 for four years..................	2513	12.25
Average yield per acre of barley for four years....................	2210	40.66

Four Year Rotation—No. 7

Plats	A	B	C	D
1897............	Wheat-1	Corn	Wheat-2	Oats
1898............	Corn	Wheat-2	Oats	Wheat-1
1899............	Wheat-2	Oats	Wheat-1	Corn
1900............	Oats	Wheat-1	Corn	Wheat-2
1901............	Wheat-1	Corn	Wheat-2	Oats
1902............	Corn	Wheat-2	Oats	Wheat-1

	Straw lbs.	Grain bu.
Average yield per acre of wheat-1 for four years..................	1825	11.46
Average yield per acre of wheat-2 for four years..................	2147	14.50
Average yield per acre of oats for four years......................	1960	39.30

Four Year Rotation—No. 8

Plats	A	B	C	D
1897............	Wheat	Corn	Oats	Millet
1898............	Corn	Oats	Millet	Wheat
1899............	Oats	Millet	Wheat	Corn
1900............	Millet	Wheat	Corn	Oats
1901............	Wheat	Corn	Oats	Millet
1902............	Corn	Oats	Millet	Wheat

	Straw lbs.	Grain bu.
Average yield per acre of wheat for four years....................	2068	13.04
Average yield per acre of oats for four years......................	2263	45.15

Four Year Rotation—No. 9

Plats	A	B	C	D
1897............	Wheat-1	Corn (manured)	Wheat-2	Oats
1898............	Corn (manured)	Wheat-2	Oats	Wheat-1
1899............	Wheat-2	Oats	Wheat-1	Corn (manured)
1900............	Oats	Wheat-1	Corn (manured)	Wheat-2
1901............	Wheat-1	Corn (manured)	Wheat-2	Oats
1902............	Corn (manured)	Wheat-2	Oats	Wheat-1

	Straw lbs.	Grain bu.
Average yield per acre of wheat-1 for four years..................	1695	11.79
Average yield per acre of wheat-2 for four years..................	2563	16.25
Average yield per acre of oats for four years......................	2133	44.76

Three Year Rotation—No. 10

Plats	A	B	C
1897	Wheat	Corn	Oats
1898	Corn	Oats	Wheat
1899	Oats	Wheat	Corn
1900	Wheat	Corn	Oats
1901	Corn	Oats	Wheat
1902	Oats	Wheat	Corn

	Straw lbs.	Grain bu.
Average yield per acre of wheat-1 for four years..................	1832	10.90
Average yield per acre of oats for four years......................	2178	42.11

Three Year Rotation—No. 11

Plats	A	B	C
1897	Oats	Fallow	Wheat
1898	Fallow	Wheat	Oats
1899	Wheat	Oats	Fallow
1900	Oats	Fallow	Wheat
1901	Fallow	Wheat	Oats
1902	Wheat	Oats	Fallow

	Straw lbs.	Grain bu.
Average yield per acre of wheat for five years......................	2560	18.66
Average yield per acre of oats for four years......................	2135	43.00

Three Year Rotation—No. 12

Plats	A	B	C
1897	Barley	Millet	Wheat
1898	Millet	Wheat	Barley
1899	Wheat	Barley	Millet
1900	Barley	Millet	Wheat
1901	Millet	Wheat	Barley
1902	Wheat	Barley	Millet

	Straw lbs.	Grain bu.
Average yield per acre of wheat for five years......................	1960	13.40
Average yield per acre of barley for three years..................	1920	34.66

Three Year Rotation—No. 13

Plats	A	B	C	
1897	Barley	Peas (cut)	Wheat	
1898	Peas (cut)	Wheat	Barley	
1899	Wheat	Barley	Peas (cut)	
1900	Barley	Peas (cut)	Wheat	
1901	Peas (cut)	Wheat	Barley	
1902	Wheat	Barley	Peas (cut)	
			Straw lbs.	Grain bu.
Average yield per acre of wheat for five years			2148	12.36
Average yield per acre of barley for three years			1630	35.00

Three Year Rotation—No. 14

Plats	A	B	C	
1897	Wheat-1	Wheat-2	Fallow	
1898	Wheat-2	Fallow	Wheat-1	
1899	Fallow	Wheat-1	Wheat-2	
1900	Wheat-1	Wheat-2	Fallow	
1901	Wheat-2	Fallow	Wheat-1	
1902	Fallow	Wheat-1	Wheat-2	
			Straw lbs.	Grain bu.
Average yield per acre of wheat-1 for five years			2254	15.10
Average yield per acre of wheat-2 for five years			1982	12.20

Three Year Rotation—No. 15

Plats	A	B	C	
1897	Wheat-1	Wheat-2	Corn	
1898	Wheat-2	Corn	Wheat-1	
1899	Corn	Wheat-1	Wheat-2	
1900	Wheat-1	Wheat-2	Corn	
1901	Wheat-2	Corn	Wheat-1	
1902	Corn	Wheat-1	Wheat-2	
			Straw lbs.	Grain bu.
Average yield per acre of wheat-1 for five years			2608	14.53
Average yield per acre of wheat-2 for five years			2490	12.40

Two Year Rotation—No. 16

Plats	A	B	
1897	Wheat	Fallow	
1898	Fallow	Wheat	
1899	Wheat	Fallow	
1900	Fallow	Wheat	
1901	Wheat	Fallow	
1902	Fallow	Wheat	
		Straw lbs.	Grain bu.
Average yield per acre of wheat for five years		2610	17.16

Two Year Rotation—No. 17

Plats	A	B
1897	Wheat	Corn
1898	Corn	Wheat
1899	Wheat	Corn
1900	Corn	Wheat
1901	Wheat	Corn
1902	Corn	Wheat

	Straw lbs.	Grain bu.
Average yield per acre of wheat for five years	2720	18.60

Two Year Rotation—No. 18

Plats	A	B
1897	Wheat	Vetch
1898	Vetch	Wheat
1899	Wheat	Vetch
1900	Vetch	Wheat
1901	Wheat	Vetch
1902	Vetch	Wheat

	Straw lbs.	Grain bu.
Average yield per acre of wheat for five years	2196	14.33

Continuous Cropping Wheat—Nos. 19, 20, 21, 22

NO. 19—NO MANURE

	Straw lbs.	Grain bu.
Yield per acre 1897	1690	6.00
Yield per acre 1898	2010	21.50
Yield per acre 1899	2380	20.67
Yield per acre 1900	1030	3.70
Yield per acre 1901	2580	16.17
Yield per acre 1902	2290	8.52
Average for five years	2058	14.11

NO. 20—MANURED EVERY FIVE YEARS

	Straw lbs.	Grain bu.
Yield per acre 1897 (manured)	2750	5.00
Yield per acre 1898	1840	22.67
Yield per acre 1899	1800	20.00
Yield per acre 1900	1110	3.17
Yield per acre 1901	2490	16.68
Yield per acre 1902 (manured)	2510	6.50
Average for five years	1950	13.80

NO. 21—MANURED EVERY THREE YEARS

	Straw lbs.	Grain bu.
Yield per acre 1897 (manured)	1400	3.88
Yield per acre 1898	2410	18.17
Yield per acre 1899	2260	18.17
Yield per acre 1900 (manured)	1640	2.67
Yield per acre 1901	3100	14.17
Yield per acre 1902	2710	9.00
Average for five years	2424	12.43

NO. 22—MANURED EVERY YEAR

Yield per acre 1897 (manured)	2980	13.66
Yield per acre 1898 (manured)	2140	19.83
Yield per acre 1899 (manured)	2670	22.17
Yield per acre 1900 (manured)	2100	4.17
Yield per acre 1901 (manured)	2950	14.17
Yield per acre 1902 (manured)	3640	11.00
Average for five years	2700	14.27

Six Year Rotation—No. 23

Plats	A	B	C	D	E	F
1902....	Wheat-1 and Brome	Brome	Brome	Flax	Wheat-2	Corn

Five Year Rotation—No. 24

Plats A	B	C	D	E
Wheat-1 and Brome	Brome	Brome	Wheat-2	Corn

The following tables give the average yields of wheat, oats and barley, from all the rotations, in convenient form for comparison. It is hoped that they will prove worthy of careful study:

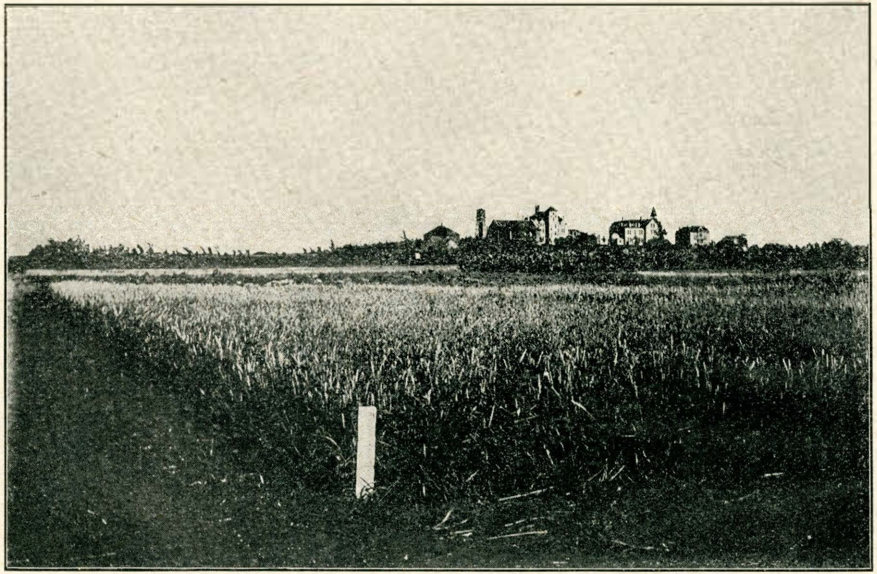
RECAPITULATION

Table V—Average Yield of Wheat per Acre for Four Years

Rotation No.	Straw lbs.	Grain bu.	Lbs. Straw per 1 lb. Grain
1—Flax, barley, millet, wheat, corn	[1]2498	15.25	2.73
2—Wheat-1, oats, peas (fed), wheat-2, roots	2315	16.41	2.35
2—Wheat-2	2228	15.16	2.45
3—Oats, wheat-1, fallow, wheat-2, corn	2103	13.04	2.69
3—Wheat-2	2378	15.40	2.57
4—Wheat-1, barley, peas (plowed), wheat-2, corn	2498	17.70	2.35
4—Wheat-2	2603	16.12	2.69
5—Wheat, oats, corn, flax, millet (fed)	2450	15.29	2.67
6—Wheat-1, barley, peas (cut), wheat-2, corn (fed)	2392	16.10	2.47
6—Wheat-2	2513	12.25	3.42
7—Wheat-1, corn, wheat-2, oats	1825	11.46	2.65
7—Wheat-2	2147	14.50	2.47
8—Wheat, corn, oats, millet	2068	13.04	2.64
9—Wheat-1, corn (manured), wheat-2, oats	1695	11.79	2.40
9—Wheat-2	2563	16.25	2.62
10—Wheat, corn, oats	1832	10.90	2.79
11—Oats, fallow, wheat	2560	18.66	2.28
12—Barley, millet, wheat	1960	13.40	2.43
13—Barley, peas (cut), wheat	2148	12.36	2.89
14—Wheat-1, wheat-2, fallow	2254	15.10	2.48
14—Wheat-2	1982	12.20	2.70
15—Wheat-1, wheat-2, corn	2608	14.53	2.99
15—Wheat-2	2490	12.40	3.35
16—Wheat, fallow	2610	17.16	2.53
17—Wheat, corn	2720	18.60	2.49
18—Wheat, vetch	2196	14.33	2.50
19—Wheat continuously, no manure	2058	14.11	2.43
20—Wheat continuously, manured every five years	1950	13.80	2.35
21—Wheat continuously, manured every three years	2424	12.43	3.25
22—Wheat continuously, manured every year	2700	14.27	3.15
Averages	2292	14.47	2.65

*Note—Rotations 1 to 10, inclusive, are for four years, and 11 to 22 for five years.

[1]Note—Where wheat occurs twice in the same rotation the first figures given are for wheat-1 and the second for wheat-2.



Wheat Continuously, Manured Every Year
Yield, 4.21 Bushels

Table VI—Average Yield per Acre of Oats for Four Years

Rotation No.	Straw lbs.	Grain bu.	Lbs. Straw for 1 lb. Grain
2—Wheat-1, oats, peas (fed), wheat, roots	2495	44.60	1.75
3—Oats, wheat-1, fallow, wheat-2, corn	2228	48.75	1.43
5—Wheat, oats, corn, flax, millet (fed)	2460	41.48	1.85
7—Wheat-1, corn, wheat-2, oats	1960	39.30	1.55
8—Wheat, corn, oats, millet	2263	45.15	1.56
9—Wheat-1, corn (manured), wheat-2, oats	2133	44.76	1.49
10—Wheat, corn, oats	2178	42.11	1.50
11—Oats, fallow, wheat	2135	43.00	1.55
Averages	2231	43.64	1.58

Table VII—Average Yield per Acre of Barley for Three Years

Rotation No.	Straw lbs.	Grain bu.	Lbs. Straw for 1 lb. Grain
1—Flax, barley, millet, wheat, corn	2075	40.20	1.07
4—Wheat-1, barley, peas (plowed), wheat-2, corn	1983	35.75	1.16
6—Wheat-1, barley, peas (cut), wheat-2, corn	2210	40.66	1.13
12—Barley, millet, wheat	1920	34.66	1.36
13—Barley, peas (cut), wheat	1630	35.00	.96
Averages	1963	37.25	1.14

EFFECTS OF THE IMMEDIATELY PRECEDING CROP UPON THE YIELDS OF WHEAT, OATS AND BARLEY

WHEAT

In Table VIII we have arranged the several rotations in groups according to the crops that immediately precede the wheat crop in each, believing that such an arrangement will give us a better chance to study the effects produced by this cause. The yields given are averages for four or five years, and the averages of these averages are also given at the foot of each group.

The following points are brought out very forcibly by this table:

1. The best average yields were obtained from wheat following summer fallow.

2. The yields obtained from wheat following corn were so nearly like those following summer fallow, a difference of less than one-third of a bushel per acre, that the rotations containing the corn crops would prove much more profitable than those containing the summer fallow.

3. The lowest yields of both grain and straw were from those rotations where wheat followed oats.

4. Wheat after millet gave yields of both grain and straw slightly below the general average for all wheat crops, and only about one bushel per acre more than continuous cropping to wheat, showing that millet has but little value as a restorative crop in a rotation.

5. The average yields of wheat following peas have been less than the general average by one-half bushel per acre. Even in the rotation where peas were plowed under for green manure, the yields have not been as good as the average where corn has been raised and harvested the previous year.

6. Continuous cropping to wheat has, thus far, resulted in an average yield of about one and one-half bushels per acre below the general average. It is altogether likely that the yields will continue to decrease under this system of continuous cropping.

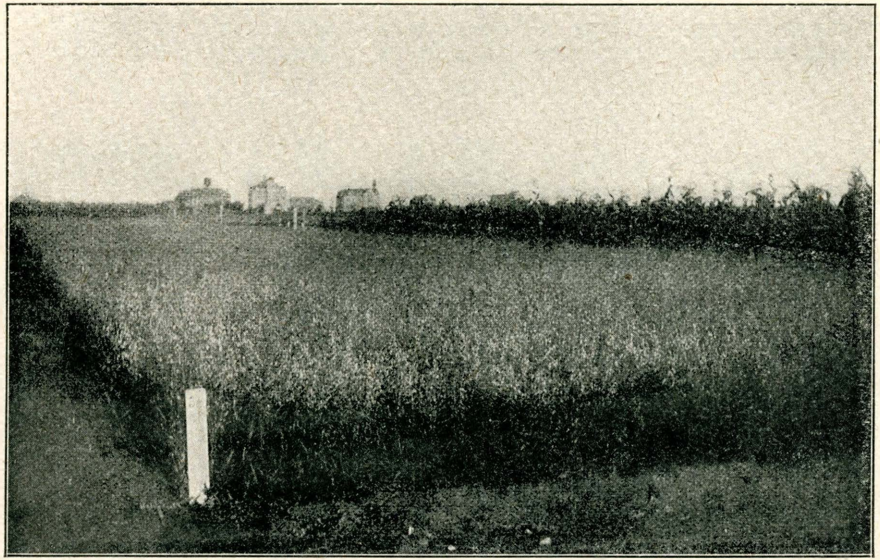
7. Wheat after roots gave about the same results as after corn.

8. Wheat after vetch gave but slightly better yields than wheat after peas.

TABLE VIII

Table Showing the Effects of the Immediately Preceding Crop upon the Yield of Wheat, Average of Four Years

Rotation No.	Straw lbs.	Grain bu.	Lbs. Straw for 1 lb. Grain
WHEAT AFTER CORN			
4-1—Wheat-1, barley, peas (plowed), wheat-2, corn	2498	17.70	2.35
6-1—Wheat-1, barley, peas (cut), wheat-2, corn (fed)	2392	16.10	2.47
7-2—Wheat-1, corn, wheat-2, oats	2147	14.50	2.47
9-2—Wheat-1, corn (manured), wheat-2, oats	2563	16.25	2.62
15-1—Wheat-1, wheat-2, corn	2608	14.53	2.99
17—Wheat, corn	2720	18.60	2.49
Averages	2488	16.28	2.56
WHEAT AFTER FALLOW			
3-2—Oats, wheat-1, fallow, wheat-2, corn	2378	15.40	2.57
11—Oats, fallow, wheat	2560	18.66	2.28
14-1—Wheat-1, wheat-2, fallow	2254	15.10	2.48
16—Wheat, fallow	2610	17.16	2.53
Averages	2450	16.58	2.46
WHEAT AFTER MILLET			
1—Flax, barley, millet, wheat, corn	2498	15.25	2.73
5—Wheat, oats, corn, flax, millet (fed)	2450	15.29	2.67
8—Wheat, corn, oats, millet	2068	13.04	2.64
12—Barley, millet, wheat	1960	13.40	2.43
Averages	2244	14.25	2.62
WHEAT AFTER PEAS			
2-2—Wheat-1, oats, peas (fed), wheat-2, roots	2228	15.16	2.45
4-2—Wheat-1, barley, peas (plowed), wheat-2, corn	2603	16.12	2.69
6-2—Wheat-1, barley, peas (cut), wheat-2, corn (fed)	2513	12.25	3.42
13—Barley, peas (cut), wheat	2148	12.36	2.89
Averages	2373	13.97	2.86
WHEAT AFTER OATS			
3-1—Oats, wheat-1, fallow, wheat-2, corn	2103	13.04	2.69
7-1—Wheat-1, corn, wheat-2, oats	1825	11.46	2.65
9-1—Wheat-1, corn (manured), wheat-2, oats	1695	11.79	2.40
10—Wheat, corn, oats	1832	10.90	2.79
Averages	1864	11.80	2.63
WHEAT AFTER WHEAT			
14-2—Wheat-1, wheat-2, fallow	1982	12.20	2.48
15-2—Wheat-1, wheat-2, corn	2490	12.40	3.35
19—Wheat continuously, no manure	2058	14.11	2.43
20—Wheat continuously, manured every five years	1950	13.80	2.35
21—Wheat continuously, manured every three years	2424	12.43	3.25
22—Wheat continuously, manured every year	2700	14.27	3.15
Averages	2268	13.20	2.83
WHEAT AFTER ROOTS			
2—Wheat-1, oats, peas (fed), wheat-2, roots	2315	16.41	2.35
WHEAT AFTER VETCH			
18—Wheat, vetch	2196	14.33	2.50



Oats after Corn
Yield, 35.00 Bushels

TABLE IX

Table Showing the Effects of the Immediately Preceding Crop upon the Yield of Oats, Average of Four Years

OATS AFTER WHEAT

Rotation No.	Straw lbs.	Grain bu.	Lbs. Straw for 1 lb. Grain
2—Wheat-1, oats, peas (fed), wheat-2, roots	2495	44.60	1.75
5—Wheat, oats, corn, flax, millet (fed)	2460	41.48	1.85
7—Wheat-1, corn, wheat-2, oats	1960	39.30	1.55
9—Wheat-1, corn (manured), wheat-2, oats	2133	44.76	1.49
11—Oats, fallow, wheat	2135	43.00	1.55
Averages	2236	42.63	1.66

OATS AFTER CORN

Rotation No.	Straw lbs.	Grain bu.	Lbs. Straw for 1 lb. Grain
3—Oats, wheat-1, fallow, wheat-2, corn	2228	48.75	1.43
8—Wheat, corn, oats, millet	2263	45.15	1.56
10—Wheat, corn, oats	2178	42.11	1.50
Averages	2222	45.34	1.50

TABLE X

Table Showing the Effects of the Immediately Preceding Crop upon the Yield of Barley, Averages of Four Years

BARLEY AFTER WHEAT

Rotation No.	Straw lbs.	Grain bu.	Lbs. Straw for 1 lb. Grain
4—Wheat-1, barley, peas (plowed), wheat-2, corn	1983	35.75	1.16
6—Wheat-1, barley, peas (cut), wheat-2, corn	2210	40.66	1.13
12—Barley, millet, wheat	1920	34.66	1.36
13—Barley, peas (cut), wheat	1630	35.00	.96
Averages	1936	36.52	1.15

BARLEY AFTER FLAX

Rotation No.	Straw lbs.	Grain bu.	Lbs. Straw for 1 lb. Grain
1—Flax, barley, millet, wheat, corn	2075	40.20	1.07

Rotation No. 1—Flax, Barley, Millet, Wheat, Corn

This has proved a fairly good rotation. The yield of wheat has been .78 bushels of grain and 206 pounds of straw per acre above the average. The barley has also yielded 2.95 bushels of grain and 112 pounds of straw more than the average, showing that, so far at least, the flax crop which preceded the barley has not proved a particularly exhaustive crop.

Where these five crops are to be grown in rotation no better combination could be suggested, except that possibly the wheat might exchange places with the barley, but we have no evidence that this would be an improvement.

Rotation No. 2—Wheat-1, Oats, Peas (fed), Wheat-2, Roots

This is also a good rotation, but as it requires one-fifth of the farm to be planted to some kind of a root crop, it will not be found suited to many farms in this state until more roots or potatoes are raised. As the results obtained from wheat following roots or potatoes are about the same as from those following corn, this crop could be substituted for roots, either in whole or in part. If it was desirable to introduce a corn crop into the rotation, without displacing the root crop, corn could be substituted for peas; the results so far showing that corn is superior to peas as a restorative crop. If neither peas nor roots were desired, corn could be substituted for both of them, and an excellent rotation would result, two-fifths being in to wheat, two-fifths to corn and one-fifth to oats.

The rotation as it has been followed on our plats has given yields of 1.94 bushels of wheat for wheat-1, .69 bushels for wheat-2, and .96 bushels for oats, above the average for these grains. The yield of wheat straw has been very near normal, being 23 pounds above for wheat-1 and 64 below for wheat-2. The yield of oat straw has been 264 pounds per acre above the average.

Rotation No. 3—Oats, Wheat-1, Fallow, Wheat-2, Corn

This is not a very satisfactory rotation, so far as it has been tried. Although one-fifth of the land has been in fallow each year, the remaining four-fifths has not produced as good yields of wheat as some rotations where all the land was cropped every year. The yield of oats, following corn, is the best we have obtained from any rotation, being 5.11 bushels per acre above the average for grain and almost exactly normal for the straw. This additional 5.11 bushels of oats would not compensate for 1.43 bushels less for wheat-1, and only .93 bushels more for wheat-2 than the average, and the loss of the use of one-fifth of the farm each year by summer fallowing. The yield of wheat straw for both crops of wheat, taken together, is 103 pounds per acre below the average, being 189 pounds below for wheat-1 and 86 pounds above for wheat-2.

A substitution of corn for summer fallow and the transposing of oats and wheat-1 would undoubtedly make a marked improvement in this rotation and would result in a rotation identical with one suggested as a substitute for No. 2, viz: Wheat, oats, corn, wheat, corn.

Rotation No. 4—Wheat-1, Barley, Peas (plowed), Wheat-2, Corn

As far as the yield of wheat is concerned, this is the best five year rotation yet tried; the yield of wheat-1 being 3.23 bushels and of wheat-2 1.65 above the average. The growth of straw has also been good, 206 pounds for wheat-1 and 321 pounds per acre for wheat-2 above the average. The greater growth of straw with a less yield of grain for wheat-2 as compared with wheat-1, making a ratio 1:2.35 for wheat-1 and 1:2.69 for wheat-2, would indicate that the plowing under of a crop of peas tended to increase the growth of straw more than the yield of grain. But a comparison of the yields of wheat-2 in this rotation, 16.12 bushels, with wheat-2, 12.25 bushels, in rotation No. 6, which is identical with No. 4, except that the peas were harvested in No. 6, while they were plowed under in No. 4, would indicate that the plowing under of peas caused an increase of 3.87 bushels of grain and 90 pounds of straw per acre.

The yield of wheat-1 in No. 4 was also 1.60 bushels greater than wheat-1 in No. 6. If we are to attribute this increased yield to the plowing under of the peas we will have 5.47 bushels of wheat to credit to this cause.

No comparison can be made between the yields of corn in the two rotations, as that in No. 6 was fed off and therefore the yield is not known.

The yield of barley was 4.91 bushels of grain and 227 pounds of straw per acre better in No. 6 than in No. 4, which is in direct opposition to the results obtained from the yields of wheat in the respective rotations.

The greater yield of wheat-1 in No. 4, as compared with wheat-1 in No. 6, would indicate that no advantage was gained by feeding off the corn, as in No. 6, compared with harvesting it, as in No. 4.

On the whole a comparison of the results from these two rotations is very perplexing and does not allow the drawing of any very definite conclusions. But as the average yield of wheat-1, after corn, was better than wheat-2, after peas, in both rotations, and as the average yield of wheat-2, taken together in both rotations, was .29 bushels less than the general average yield of all crops of wheat, it must be admitted that the theory of the beneficial effects of raising a nitrogen gathering crop, like peas, either to plow under or to harvest, is not supported by the evidence in this case. It may be, however, that the benefits will become more apparent in subsequent crops.

From the evidence so far obtained it would seem that a substitution of a corn crop in place of the peas in both rotations would be an improvement, and that it would make very little difference whether the corn was fed off on the ground or harvested.

If we were to make this substitution of corn for peas we would have a rotation identical with that already twice suggested in connection with rotations No. 2 and 3, except that barley would be put in the place of oats, as follows: Wheat-1, barley, corn, wheat-2, corn. If less wheat and more coarse grain for feeding were desired in the rotation, the following would seem to be a good one: Barley, oats, corn, wheat, corn, or, perhaps, better still, wheat, oats, corn, barley, corn.

Rotation No. 5—Wheat, Oats, Corn, Flax, Millet (fed)

Where the conditions are such as to make it desirable to introduce a crop of flax into the rotation without having sod to sow it on, and also to provide a field of millet either for pasture or hay, this rotation should prove fairly satisfactory. The yield of wheat is .82 bushels of grain and 158 pounds of straw above the average and is the best of any rotation except those where wheat follows either corn, roots or fallow. The yield of oats is not so satisfactory, being 2.16 bushels less than the average of all, and 1.15 bushels less than the average of oats after wheat in all rotations. The yield of oat straw is, however, 229 pounds above the average, which would indicate a good growth.

The fact that the yield of wheat in this rotation was almost identical with that in rotation No. 1, where wheat follows millet which was cut, would indicate that there was no advantage to the following crop in feeding the millet off instead of harvesting it. This agrees with our experience in feeding off corn, as noted in the discussion of rotations No. 4 and 6.

After raising a crop of corn the land ought to be reasonably clean and in good condition for flax. The late plowing of the flax stubble and the raising of a crop of millet should keep the land clean and in good condition for the wheat and oats which follow.

Rotation No. 6—Wheat, Barley, Peas (cut), Wheat-2, Corn (fed)

This rotation has been discussed in connection with rotation No. 4.

Rotation No. 7—Wheat-1, Corn, Wheat-2, Oats

The results from this rotation have so far been very unsatisfactory. Even wheat-2, which follows corn, is only just barely above the average in grain and is 145 pounds short in straw, while wheat-1 is 3.01 bushels per acre of grain and 467 pounds of straw below the average. The yield of oats is 4.34 bushels of grain and 271 pounds of straw short, making the poorest yield of any rotation in both grain and straw.

It is difficult to account for the low yields of all three crops in this rotation. A transposition of oats and wheat-1 would undoubtedly raise the yield of that crop of wheat, as it has been proved that wheat does better after wheat than after oats. But such a change could not reasonably be expected to improve the yield of oats nor of wheat-2, which is the lowest one obtained where wheat follows corn.

Had not the uniformity of the soil upon which this rotation and No. 8 are located with that of other portions of the tract been fully established before these rotations were begun, the inference would be strong that this soil was poorer. Future results may help to explain these low yields.

Rotation No. 8—Wheat, Corn, Oats, Millet

The yield of wheat in this rotation has not been satisfactory, being the lowest of any rotation where wheat has followed millet. The yield of grain has been 1.43 bushels per acre and of straw 224 pounds below the general average. The yield of oats has been 1.51 bushels per acre and 32 pounds of straw above the general average, and very near the average of all oat crops following corn.

The rotation could undoubtedly be improved by transposing the positions of oats and wheat, thus making it oats, corn, wheat, millet. This change would probably improve the yield of wheat by at least three bushels per acre, while it would not be likely to reduce the yield of oats as many bushels. The value of a bushel of wheat being from three to four times that of a bushel of oats, the total value of the returns from the rotation would be materially enhanced, as it is not likely that the yields of corn and millet would be greatly changed.

Rotation No. 9—Wheat-1, Corn (manured), Wheat-2, Oats

In this rotation we again see the bad effects of wheat following oats, the yield of wheat-1 being 4.46 bushels per acre of grain and 868 pounds of straw less than wheat-2 in the same rotation, and 2.68 bushels of grain and 595 pounds of straw per acre less than the general average.

The yield of wheat-2 is 1.78 bushels per acre of grain and 271 pounds of straw above the general average for all crops of wheat, but almost exactly the average of all crops of wheat following corn. This would indicate that little or no beneficial effects were produced in the yield of grain in the wheat crop following the manuring of the corn. The yield of straw was, however, raised 81 pounds per acre above the average for wheat following corn.

The results obtained from the corn plats have not been very satisfactory or reliable for the reasons already mentioned in the general description of the work. But from all available data there is no evidence that the yield of corn was materially improved by the manuring.

The positions of wheat and oats should be exchanged for the same reasons as those mentioned in the discussion of Nos. 3, 7 and 8.

Rotation No. 10—Wheat, Corn, Oats

This rotation furnishes additional evidence of the bad effects of a crop of oats coming before a crop of wheat, the yield of grain being 3.57 bushels per acre and of straw 399 pounds less than the general average, making it the lowest yield of any wheat crop in the rotations.

An interpretation of the results of this rotation is seriously complicated by the exceptionally low yield of oats following corn. The yield is 1.53 bushels per acre of grain and 114 pounds of straw below the general average, and 3.23 bushels per acre and 44 pounds of straw below the average for oats following corn. In fact the yield of both grain and straw is less than for the average of oats following wheat.

The relative positions of wheat and oats in the rotation should unquestionably be changed, which would doubtless improve the yield of wheat, but we will not attempt to account for the low yield of oats.

Rotation No. 11—Oats, Fallow, Wheat

This is the rotation that has so far given the largest yield of wheat per acre, being followed very closely by No. 17, wheat and corn alternately. But as this rotation involves the fallowing of one-third of the farm each year, it would be necessary to regard the average yield as two-thirds of that given, or an average of 12.43 bushels every year, instead of 18.66 bushels per acre two years out of three, in order to make it comparable with other rotations in which all of the land is cropped every year. The fallowing would involve one extra plowing, but to offset this would be the saving of one year's seed and the fitting and seeding of the crop, which would just about balance accounts. We would then have the cost of harvesting and stacking, the better quality of the grain and the improved condition of the land, as regards weeds and tilth, in favor of the fallowing.

It will be seen by consulting Table V that calculated in this way, this rotation has yielded greater average returns of wheat than certain wheat crops in seven out of the thirty rotations, being wheat-2 in No. 6, wheat-1 in No. 7, wheat-1 in No. 9, wheat in No. 10, wheat in No. 13, wheat-2 in No. 14 and wheat-2 in No. 15, and identically the same as the yield of wheat in No. 21, wheat continuously, manured every three years. Wheat-1 in No. 3, wheat in No. 8, No. 12 and No. 20 exceed in yield that of this rotation by so small an amount that the other advantages mentioned would turn the balance in favor of this rotation as compared with them. Wheat occurs twice, however, in rotations No. 6, 7, 14 and 15, so the averages of the two crops of wheat in each should be taken, which would give us for No. 6 14.17, No. 7 12.98, No. 14 9.10, and No. 15 13.46 bushels per acre. Even on this basis it will be seen that none of the yields so far exceed that of No. 11 that it is at all certain that they would prove more profitable.

Rotations No. 3 and 14 each have a fallow as well as two crops of wheat. Averaging the two crops of wheat in each and taking four-fifths of this average in the case of No. 3 and two-thirds in the case of No. 14, and we have an average yield of wheat in No. 3 11.37 bushels and in No. 14 9.10 bushels per acre, which is less than that of No. 11.

The yield of oats in this rotation is nearly normal, which gives further evidence of the fact that the oat crop is not nearly so susceptible to the influences of the preceding crop as is wheat.

On the whole the results from this rotation compare very favorably with those from the other rotations mentioned. Where it is not desirable for any reason to introduce corn into the rotation, this rotation would probably prove very satisfactory.

A comparison of the relative value of corn and fallow in the rotation will be made further on in this Bulletin.

Rotation No. 12—Barley, Millet, Wheat

The results so far obtained from this rotation have been very unsatisfactory. The yield of barley is the lowest of any rotation, being of grain 2.59 bushels per acre and of straw 43 pounds below the general average, and 1.56 bushels of grain and 16 pounds of straw per acre below the average of all barley crops following wheat.

The yield of wheat is 1.07 bushels per acre and 332 pounds of straw below the general average, and .85 bushels of grain and 284 pounds of straw below the average for all crops of wheat following millet.

We are unable to give any satisfactory or plausible explanation for the low yields obtained in what would seem to be a very fair rotation. The location of the plats in relation to others that have given good returns makes it seem highly improbable that the soil is poorer than that of the neighboring plats.

Rotation No. 13—Barley, Peas (cut), Wheat

This rotation is the same as No. 12, except that peas have been substituted for the millet. The results are much the same, the wheat yielding 2.11 bushels per acre and 144 pounds of straw, and the barley 2.25 bushels of grain and 333 pounds of straw less than the general average. This is the lowest yield of barley straw and within a third of a bushel of the lightest yield of barley grain obtained from any of the rotations.

Except the negative evidence that it furnishes concerning the value of peas in a rotation, little can yet be learned from these results.

Rotation No. 14—Wheat-1, Wheat-2, Fallow

Rotation No. 15—Wheat-1, Wheat-2, Corn

These two rotations are identical, except that in No. 15 corn takes the place of fallow in No. 14. The yields in neither of these are very satisfactory. Taking the average of the two wheat crops in each rotation we have 13.65 bushels per acre for No. 14 and 13.46 bushels for No. 15, a difference so small as not to be worth considering. But when we consider that No. 14 raised but two crops in three years, we find that we should credit it with but two-thirds of this yield, or 9.10 bushels per acre, which places it far below the average. Rotation No. 15 is also about one bushel per acre below the average. We are unable to account for these low yields. From all we know about the effects of the relation of the different crops in rotation, No. 14 should have given as good or better results than No. 11, which is the same except that a crop of oats is substituted for one crop of wheat. This substitution of oats for wheat should rather lower than raise the average yield of wheat. But as a matter of fact the yield of wheat following fallow in No. 11 was 3.56 bushels per acre better than in No. 14.

The close agreement between the yields of grain in Nos. 14 and 15 adds more evidence that a corn crop leaves the soil in just as good condition for wheat as does a summer fallow.

It is a remarkable fact, and one not easily accounted for, that while the yield of grain was nearly the same in Nos. 14 and 15, the yield of straw was 431 pounds per acre higher on the corn ground of No. 15 than on the land that had been fallowed in No. 14.

As a means of comparing the value of corn and fallow these results are valuable and interesting, but it is feared that a comparison of either or both of them with some of the other rotations that have given better results may be misleading.

It is hoped that future results may throw more light upon these questions.

Rotation No. 16—Wheat, Fallow

Rotation No. 17—Wheat, Corn

These two rotations give us another chance to compare the value of corn and fallow as a preparation for wheat. In both of these the yields are very satisfactory, the advantage being on the side of the corn by 1.44 bushels of grain and 110 pounds of straw per acre.

Even the most enthusiastic advocate of summer fallowing would hardly adopt a rotation like No. 16, where one-half of the farm would be in fallow every year. It does, however, teach us a valuable lesson concerning what can reasonably be expected from summer fallowing.

On the other hand, No. 17 is a throughly practical rotation, and one that might be adopted to advantage by many of the farmers of the state, particularly in the drier portions, where neither oats nor barley do as well as wheat and corn.

It will be very interesting to note the effects of these two rotations through a long term of years, as the results will answer many interesting questions. For instance: How long can we continue to take a crop off every year without making any return to the soil, as in No. 17, and obtain as good or better crops **every year** as we do every two years in the case of No. 16? Is the soil an inexhaustible storehouse of fertility upon which we can draw as frequently and as heavily as the physical conditions of the soil will permit without appreciable diminution in the crops obtained? These are only a few of the very important questions that may be answered by the continuation of these rotations.

Rotation No. 18—Wheat, Vetch

This rotation was not adopted as one likely to be found desirable by the farmers of the state, but for the purpose of studying the effects of growing a nitrogen gathering crop every alternate year. Vetches have grown well, but we do not consider them equal to the common field pea as a grain or forage crop, and as yet we have not been able to find any benefit to the soil from the introduction of any kind of a legume into the rotation. The yield of the wheat in this rotation is slightly below the average both in grain and straw.

Rotations Nos. 19, 20, 21 and 22—Continuous Cropping to Wheat

We give the yield from these plats for each year in order that we may learn, if possible, the effects of manuring. The yields for the first year, 1897, are not included in the averages, in order that these averages may be comparable with those of the rotations.

All of the plats, except No. 19, were manured in 1897; No. 20 also in 1902; No. 21 in 1900 and No. 22 every year since 1897. The results when studied in detail are very difficult to interpret. The averages for the five years, 1898 to 1902, inclusive, are somewhat less perplexing, but are far from satisfactory or decisive. The average yield from Plat 22, manured every year, exceeds that from Plat 19, which received no manure, by only .16 of a bushel, a difference so slight as to be of no significance whatever. The yields from Plats 20 and 21, which have received two applications of manure, are both less than for Plat 19, which has received no manure.

The comparatively large yield, more than twice that of any of the other three plats, of Plat 22 for 1897, the first year that manure was applied to all the plats, except No. 19, is difficult to explain. Plat 20, manured, yielded 1 bushel per acre, and Plat 21 2.12 bushels less than Plat 19, which was not manured.

In 1900 Plat 21, which was manured, yielded less than either

Plats 19 or 20, which were not, while Plat 22, which was also manured, yielded more than any of the others.

In 1902 like comparative results were obtained from Plat 20, which was manured.

In attempting to ascertain the effects upon the next year's crop of the application of manure, we meet with no better success. In 1898, the year following the application of manure to all the plats except Plat 19, we find that Plat 20 alone yielded 1.17 bushels per acre more than Plat 19, while Plats 21 and 22 yielded 3.33 and 1.67 bushels per acre less, respectively, than Plat 19. In 1901 Plat 21, which had been manured the previous year, yielded 2 bushels per acre less than Plat 19, which had received no manure for many years, and 2.51 bushels less than Plat No. 20, which had not been manured since 1897, while it yielded exactly the same as Plat 22, which had received an application of manure every year since 1897.

The growth of straw has been better on Plat 22 every year than on any of the other plats, with the single exception of Plat 21 in 1898, which had not received any manure for that year, but had been manured the previous year. The average yield of straw from Plat 22 has been considerably better than from any of the other plats, being 642 pounds per acre more than for Plat 19, 750 pounds more than for Plat 20, and 376 pounds more than for Plate 21.

On the whole we are forced to admit that our rotation experiments so far do not furnish any evidence of the beneficial effects from the application of manure to wheat except the rather doubtful one of increasing the growth of straw in certain instances. A further discussion of this question will be given in the latter part of this Bulletin, under the head of "Applying Manure to Wheat." A comparison of the yields obtained from continuous cropping and rotations will be made in the general summary.

Rotation No. 23—Wheat-1, Brome, Brome, Flax, Wheat-2, Corn

Rotation No. 24—Wheat-1, Brome, Brome, Wheat-2, Corn

These two rotations were not begun until the spring of 1902, and were introduced to test the comparative value of rotations containing a perennial grass crop. They are alike, except that one contains a flax crop and the other does not. It is believed that either one would prove a satisfactory rotation for a large part of the state.

Brome grass has proved a valuable grass both for pasture and meadow, and it is believed that it will be found well adapted for use in rotation. It catches readily when sown with wheat and produces a good crop, especially of seed, the following year. The second year after sowing it usually yields a good crop of both seed and hay. As the meadow becomes older it has a tendency to become turf-bound and the yield of seed, and in some cases also of hay, is materially reduced. For permanent pasture this characteristic of producing a very tough sod is a marked advantage, but it is undoubtedly true that where seed and hay are desired it will be found desirable to break up the sod after about the third or fourth year. The rotation could be prolonged by continuing the meadow for three or four years and introducing more crops into it. For instance, on a quarter section where hay was to be made an important feature, the following ten year rotation might be adopted: 1, wheat, seeded to brome; 2, brome; 3, brome; 4, brome; 5, brome; 6, flax; 7, oats or barley; 8, corn; 9, wheat, 10, corn.

This could be modified in many ways. For instance, oats, barley, millet or peas could be substituted for either or both of the wheat crops. Roots or potatoes could be substituted in part, or in whole, for one or both of the corn crops, etc., etc.

Taking the ten year rotation as suggested above, we would have, as soon as it was fully established, the following distribution of crops: There would be ten fields of sixteen acres each. Nos. 1 and 9 would be into wheat, thirty-two acres;

Nos. 2, 3, 4 and 5 would be brome meadow, or pasture, sixteen acres of which would be one year old, sixteen acres two years old, sixteen acres three years old and sixteen acres four years old, sixty-four acres in all; No. 6 would be into flax, sixteen acres; No. 7 oats or barley, sixteen acres; Nos. 8 and 10 corn, thirty-two acres, making one hundred and sixty acres in all.

Going back to our original proposition as outlined in rotation No. 23, we would have the following distribution of crops:

The farm would be divided into six fields of twenty-six and two-thirds acres each. Two of these would be in to wheat, fifty-three and one-third acres; two in to brome, fifty-three and one-third; one in to flax, twenty-six and two-thirds; and one in to corn, twenty-six and two-thirds acres, making one hundred and sixty acres in all.

If rotation No. 24 were adopted on a quarter section, it would be divided into five fields of thirty-two acres each. Two of these would be in to wheat, sixty-four acres; two in to brome, sixty-four acres; and one in to corn, thirty-two acres, making one hundred and sixty acres in all.

It is believed that some one of these rotations, either as they are given, or modified as suggested, would be found suited to the needs of many South Dakota farms. In all these rotations either wheat or flax is made to follow the breaking up of the brome grass sod. Our experience in raising crops on this kind of sod land leads us to believe that excellent crops of either of these grains can usually be raised and that the soil would be in splendid condition for the crop of corn or wheat which was to follow. Wheat after corn gives uniformly good returns, so it is fair to assume that all of the crops in such a rotation would be far above the average now obtained on most farms. A long rotation involving small fields would have some advantages over a short one with larger fields. In the ten year rotation only sixteen acres are to be seeded to brome each year, while there is to be sixty-four acres of meadow every year. In the case of a failure to secure a catch of brome grass in an unfavorable year there would still be forty-eight acres of meadow for the following year. Another small grain crop could be sown on the field that failed to catch and seeded to brome, and millet could be substituted for one of the grain crops, which would come in the regular rotation. In this way the balance between the amounts of grain and forage or hay could be preserved.

We have had good results from breaking brome grass sod about the first of July, after an early hay crop has been cut, allowing the sod to lie until the following spring and then fitting it with a disc for a grain crop. Possibly earlier breaking and sowing to flax would prove more satisfactory in some cases. Under either plan a crop would be secured every year and there would be no loss of time in subduing the brome sod.

We are fully convinced that brome grass properly used in a rotation, or for permanent pasture, will prove an inestimable boon to the farmers of the state, but that it cannot be relied upon for a meadow for more than three or four years. If this tendency to become turf-bound in three or four years results in inducing the farmers of this state to adopt some good systm of rotation into which brome grass will enter, it may be that the indirect benefits arising in this way will be even greater than the direct one of furnishing an excellent hay and pasture grass.

Another very strong point in favor of brome grass, both as a pasture and a meadow grass, that has not been mentioned, but is worthy of consideration, is the fact that it starts about two weeks earlier in the spring and remains green longer in the fall than any other grass. It will furnish pasture about as early in the spring as winter rye, and in a favorable season can be cut for hay in June.

The most important lesson to be learned from the above facts is to **raise corn.** If for no other reason than to put your land in good condition for raising wheat, raise corn. If proper care is given to the selection of seed corn and the crop is given the necessary culture and the grain is fed upon the farm, the corn crop will be a profitable one in nearly all parts of the state. But even if it does not yield a large direct profit, it will pay in the long run to raise corn as a restorative crop. Some of the best farmers of the state have already come to the conclusion that it does not pay to raise wheat except upon corn stubble; our results point to the same conclusion.

Just how or why a corn crop produces the beneficial effects upon the soil that it does is not fully understood. More than twenty years ago, Professor W. O. Atwater of Connecticut wrote: "The corn plant has in these trials shown itself capable of getting on and bringing fair yields with but relatively small amounts of the less costly mineral fertilizers, even in the worn-out soils of the eastern states. With this help, corn has gathered its nitrogen from natural sources, and holds it ready to be fed out in the farm and returned in the form of manure for other crops. In other words, the experiments thus far imply that corn has somehow or other the power to gather a great deal of nitrogen from soil, or air, or both; that in this respect it comes nearer to the legumes than the cereals. That, in short, corn can be classed with the 'renovating' crops. If this is really so, and this can be settled only by continued experimenting, our great cereal, instead of being simply a consumer of the fertility of our soils, may be used as an agent for its restoration." Since this was written something has been learned concerning the work of bacteria in the soil, but it has not yet been proved that corn is a nitrogen gatherer in the same sense that the legumes are, but the value of corn as a restorative crop has been abundantly proved. It is now generally believed that the physical effects produced upon the soil by growing and cultivating a crop of corn are of much greater importance than any actual addition to the soil of plant food, by the corn plant as a nitrogen gatherer.

But it is also true that a soil kept all summer in the best condition for the growth of a crop of corn is also in ideal condition for many bacteriological and chemical changes that are constantly going on in a well-tilled soil, and are highly beneficial in making available, if not actually obtaining from the air, the elements of plant food. Professor King has shown that the supply of both the total soluble salts and the nitrates is considerably larger in a soil that has raised a crop of corn and has been properly cultivated than in one that has raised a crop without cultivation. His results support the theory that it is not so much the actual amount of fertility taken from the soil by any crop that will influence the yield of the succeeding crop, as the physical condition of the soil during and at the close of the season. There is plenty of evidence furnished, not only by the results of our experiments, but also by those of other investigators, that the store of available plant food at the close of the season is considerably greater in a soil that has been thoroughly cultivated during the season than in one that has not, independently of the draft made upon the soil by the crop raised. But until some better method than we have at present is devised for determining the available plant food in the soil, direct evidence from laboratory determination can not be furnished.

A long series of experiments conducted at this Station, an outline of which has been published in Bulletin No. 58, the results of many other experimenters and of practical farmers, show that moisture is conserved by frequent cultivation. An examination of Table XII will show that there is also considerable difference in the amounts of water actually taken from the soil by the several crops under consideration, and that corn has the advantage of all the crops in this respect.

It will be seen, then, that at least a part of the beneficial effects upon succeeding crops produced by raising a crop of corn are due to the following causes:

1. The soil is kept in the best condition for the growth of nitrifying and other beneficial bacteria.

2. Chemical changes, in part dependent upon, and in part independent of, the growth of bacteria are induced; thus reducing the unavailable plant food to forms in which it can be readily assimilated by the growing plants.

3. The soil moisture is conserved and kept stored in the

soil for the use of the succeeding crop, instead of being evaporated from the surface.

4. A less amount of moisture is used by the corn crop than by any of the other crops under consideration; and therefore a larger store of soil water is available for the succeeding crop.

The following table has been calculated from data obtained from various sources. The percentages of nitrogen, phosphoric acid and potash for the several grains, straws and cobs are from the table published by the United States Office of Experiment Stations in the Handbook of Experiment Station Work, Bulletin No. 15. The amount of water required to produce a ton of dry matter of the several crops is from King's Physics of Agriculture, using round numbers. The yields of grain, straw, stalks and cobs per acre are from the results of our own experiments upon the rotation plats for five years, and are given in round numbers.

As no moisture determinations are made upon the grain, straw, etc., we have assumed a uniform water content of ten per cent in the air dry substance.

It will be seen that these figures differ somewhat from those published by others. This difference is due in part to the difference in relative weight of the grain and the straw, or stalks, assumed by others. As our figures are from actual determinations, extending over a period of five years, and are based upon averages of a large number of plats, we feel confident that they come much nearer representing average yields in this state than any heretofore published.

Some writers have used the results of foreign analyses as a basis for their computation, or have taken the tables entire from foreign publications based upon very different conditions from our own. The only superiority we claim for these figures is that they are more representative of local conditions.

TABLE XI

Table Showing the Comparative Draft upon the Soil, of Plant Food and of Water by Different Crops

			Nitrogen		Phosp. Acid		Potash		Dry Matter			Water Used	
		Weight	Per cent	lbs.	Per cent	lbs.	Per cent	lbs.	Pounds	Tons	Per Ton of Dry Matter Tons	Per Acre Tons	Per Acre Inches
CORN 30 bushels per acre 2,200 pounds stalks	Grain	1680	1.82	30.58	.70	11.76	.40	6.72					
	Cobs	420	.50	2.10	.06	.25	.60	2.52					
	Stalks	2200	1.04	22.88	.29	6.38	1.40	30.80					
	Total........	4300		55.56		18.39		40.04	3870	1.935	271	524.38	4.63
WHEAT 15 bushels per acre 2,300 pounds straw	Grain	900	2.36	21.24	.70	6.30	.39	3.51					
	Straw	2300	.59	13.57	.12	2.76	.51	11.73					
	Total........	3200		34.81		9.06		15.24	2880	1.440	453	652.32	5.76
OATS 45 bushels per acre 2,300 pounds straw	Grain	1440	2.06	29.66	.82	11.80	.62	8.93					
	Straw	2300	.62	14.26	.20	4.60	1.24	28.52					
	Total........	3740		43.92		16.40		37.45	3370	1.685	504	849.24	7.49
BARLEY 40 bushels per acre 2,200 pounds straw	Grain	1920	1.51	28.99	.79	15.17	.48	9.22					
	Straw	2200	1.31	25.15	.30	5.76	2.09	40.13					
	Total........	4120		54.14		20.93		49.35	3708	1.854	464	860.26	7.59

In comparing corn, wheat, oats and barley it will be seen that corn is the greatest consumer of nitrogen; barley of potash and phosphoric acid. Wheat uses less of each of these elements of fertility than any of the other crops. Judged, then, entirely from the standpoint of the chemist, barley would seem to be the most exhaustive crop, then corn, oats and wheat, in the order named. We find, however, that the corn crop uses only 4.63 acre inches of water, while barley requires 7.59 inches, oats 7.49 inches, and wheat 5.76 inches. Viewed, then, from the standpoint of the soil physicist, corn would be the least exhaustive of soil moisture, then wheat, oats, and barley, in the order named. This arrangement agrees much more closely with the results of practical farmers than that based upon purely chemical considerations. It is not generally believed, however, that barley is a more exhaustive crop than oats. Our own experiments do indicate that it requires more water. Our barley failed entirely in 1900 from a lack of moisture, while oats yielded from 13 to 35 bushels per acre. It is not at all difficult to see why "oats is hard on the soil," as is so generally recognized by farmers, nor why wheat should yield so much larger returns when sown after corn than after oats. There was enough more moisture left in the soil after the corn than after the oats, 2.86 inches, to supply half the water needed by the wheat. It is not claimed that this is the only way in which the wheat was benefited by the corn, but it was undoubtedly an important factor.

Admitting that corn is an exhaustive crop as far as the plant food it takes from the soil each year is concerned, it does not necessarily follow that the raising of corn will exhaust the fertility of the farm. On the contrary, it will conserve the fertility, for more corn means more stock to eat it, and therefore more manure to be returned to the soil. This brings us back again to the proposition that the problems involved in crop rotation, or more generally speaking, farming in this state, are physical rather than chemical. Next, or perhaps equal in importance, are physiological considerations, the producing of plants adapted to our conditions. We have some very extensive experiments along this line under way, but cannot discuss them at this time.

The failure to obtain any beneficial results from growing peas and vetch, which are true nitrogen gatherers, has been somewhat disappointing and would indicate that the soil is not greatly in need of nitrogen. It is too soon, however, to condemn these crops, as their beneficial effects may be seen in time.

The failure to get better yields from wheat following millet does not support the opinion that millet is in any sense a restorative crop. It is quite probable that the good crops of wheat sometimes obtained when sown on millet stubble have been due to the late plowing for the millet and the quick growth of that crop, keeping the land free from weeds. Wheat is also frequently drilled in upon millet stubble without plowing, and there is little doubt but that better results are sometimes obtained in this way than when the ground is plowed every year. The same thing is true of drilling in wheat upon corn stubble without plowing. Of course these considerations do not apply to our yields, as all our plats are plowed in the fall.

OATS

In our rotations oats have been raised after corn and after wheat, with the results given in Table IX. The average yield of oats after corn has been only 2.71 bushels of grain per acre better than where it was raised after wheat, and the yield of straw has been almost the same in both instances, the very insignificant difference of fourteen pounds per acre being in favor of oats after wheat. These results are somewhat surprising, when compared with the very marked advantages obtained from raising wheat after corn, and would seem to prove that it does not pay to raise oats upon corn stubble, when so much better yields of wheat can be obtained by using the corn ground for wheat. Where these three crops enter into a rotation the order should be corn, wheat, oats.

BARLEY

As shown by Table X, barley has been raised after wheat and after flax. The yield of barley after flax being 3.68 bushels better than after wheat would indicate that flax is not a particularly exhaustive crop, as is generally believed.

The popular prejudice against flax is not well founded. Professor Snyder of the Minnesota Experiment Station says: "Flax does not remove an excessive amount of fertility from the soil. An average yield of fifteen bushels of flax per acre will remove less fertility from the soil than one hundred and fifty bushels of potatoes, forty-five bushels of corn or thirty bushels of wheat." Professor H. L. Bolley of the North Dakota Station has shown in Bulletin No. 50 of that Station that the cause of the failure of flax where sown continuously upon the same soil is due to a fungus disease which is peculiar to the flax plant, but does not affect other crops. Flax may thus safely enter into any rotation, but should not be grown frequently on the same ground. As it is very important that the land should be free from weeds, flax should be raised upon sod land, or after corn or root crops.

From the above considerations it would seem that we must rely almost entirely upon corn and roots, in our rotations, as restorative crops. It is believed that seeding the land down to brome grass and turning under the sod will also prove of great benefit in keeping up the supply of humus in the soil.

COMPARISON OF THE EFFECTS UPON THE YIELDS OF WHEAT AND OATS PRODUCED BY THE IMMEDIATELY PRECEDING CROP IN AN UNFAVORABLE AND A FAVORABLE SEASON

In our discussions heretofore we have used the average yields for a term of years as the basis for our conclusions and suggestions. But in order to bring out more forcibly the effects of the preceding crop, due, it is believed, to the physical conditions of the soil, we give in Table XIII the average yields of groups of plats for the year 1900, which was the most unfavorable one in the series, and for 1901, when fair average crop conditions prevailed.

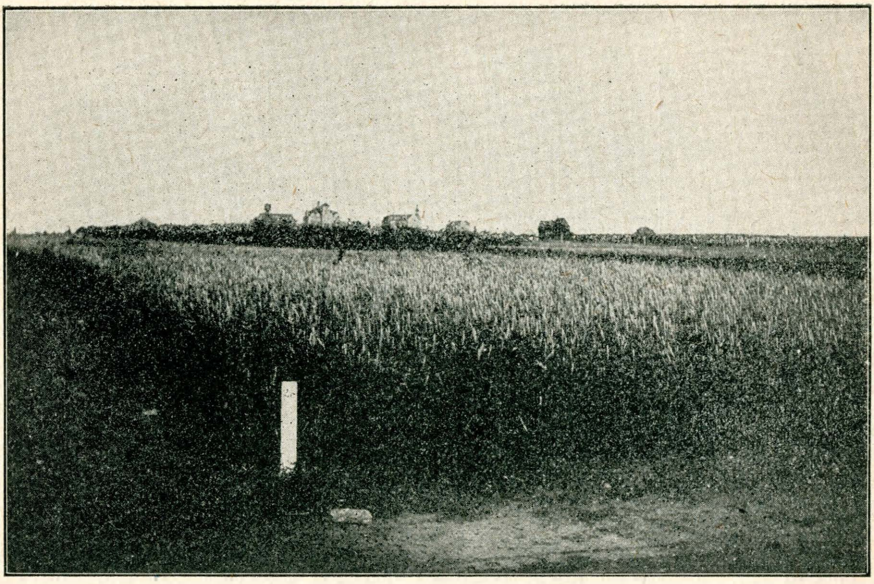
In order to show more clearly what climatic conditions combine to make a favorable or an unfavorable season for crop production, we give below, Table XII, the monthly precipitation, the monthly and average daily evaporation from an open tank of water exposed at the surface of the ground, and the mean temperature for the growing months of May, June, July and August for the period of five years, covered by our rotation experiments. We also give the term and seasonal averages.

The amount of evaporation was obtained by placing fifteen inches in depth of water in an iron tank three feet in diameter and twenty inches deep, set in the ground so that the upper rim is about two inches above the surface. The tank is surrounded with a wire netting to protect it from molestation, but is fully exposed to the elements, receiving all the rain and sunshine that occurs. The height of the surface is carefully measured every ten days and a comparison made between the change of level during the period and the precipitation which has occurred since the last reading. The precipitation is measured with a government rain gauge located near the evaporation tank. The figures given in the table are summaries of results obtained in this way. It is believed that a careful study of this table will help to explain some questions about which there is much popular misunderstanding.

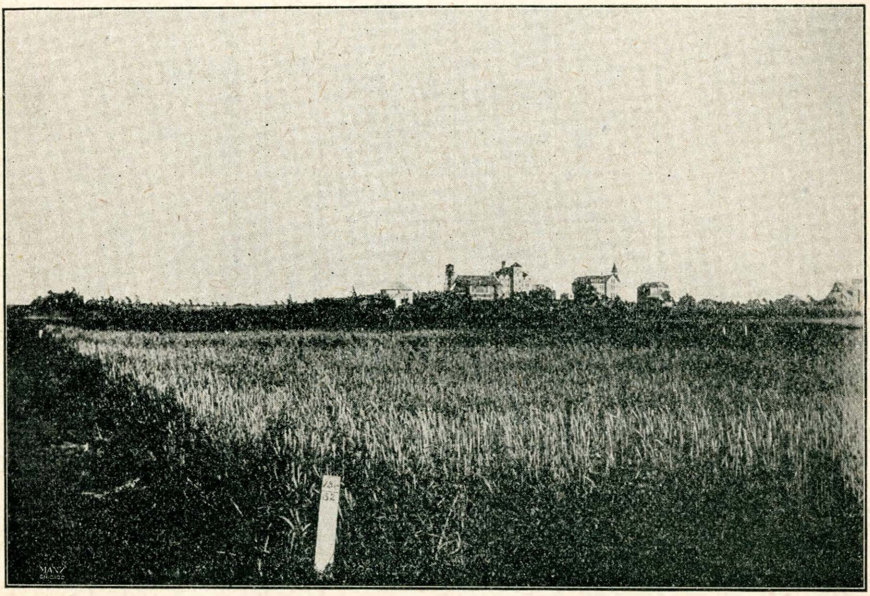
TABLE XII

Table Showing Precipitation, Evaporation and Temperature for Growing Season for Five Years

	May				June				July				August				Season—Four Months				
	Precipitation Inches	Evaporation Inches	Aver. Daily Evaporation Inches	Mean Temp. for Month Degrees	Precipitation Inches	Evaporation Inches	Aver. Daily Evaporation Inches	Mean Temp. for Month Degrees	Precipitation Inches	Evaporation Inches	Aver. Daily Evaporation Inches	Mean Temp. for Month Degrees	Precipitation Inches	Evaporation Inches	Aver. Daily Evaporation Inches	Mean Temp. for Month Degrees	Total Precipitation Inches	Total Evaporation Inches	Excess Evaporation Inches	Aver. Daily Evaporation Inches	Mean Aver. Temp. deg.
1898	5.15	3.49	.113	54.5	1.94	3.19	.106	66.3	1.56	4.19	.133	70.4	2.78	3.48	.112	69.6	11.43	14.35	2.92	.116	65.2
1899	3.38	2.69	.087	55.2	5.42	4.23	.141	64.8	.73	4.98	.161	69.2	3.25	3.88	.125	69.4	12.78	15.78	3.00	.128	64.6
1900	1.23	5.32	.171	60.0	1.62	4.10	.136	66.1	5.10	3.00	.097	68.2	4.00	2.00	.065	74.0	11.95	14.42	2.47	.117	67.1
1901	1.80	2.70	.087	57.0	4.51	3.90	.130	65.9	1.66	5.57	.179	76.2	2.94	4.24	.137	70.4	10.91	16.41	5.50	.133	67.4
1902	2.66	2.56	.082	58.2	3.17	3.77	.126	60.2	2.75	3.48	.112	69.6	5.30	3.39	.109	65.1	13.88	13.20	—68	.107	63.2
Averages.....	2.85	3.35	.108	57.0	3.33	3.84	.128	64.7	2.36	4.24	.136	70.7	3.65	3.40	.109	69.7	12.19	14.83	2.64	.120	65.5
Excess evaporation............		.50				.51				1.88				—25					2.64		



Wheat after Roots
Yield, 13.33 Bushels



Wheat after Peas
Yield, 3.16 Bushels

It will be seen that the average total evaporation for the season, for the period of five years, is 14.83 inches, and that the average total precipitation for the same period is 12.19 inches, showing that the evaporation has averaged 2.64 inches greater than the precipitation. Only one year out of the five has the precipitation exceeded the evaporation, 1902, and then by only .68 inches. Contrary to what might be reasonably expected, the greatest excess of evaporation over precipitation, 5.5 inches, occurred in 1901, which was a fairly favorable season, and next to the lowest excess, 2.47 inches, occurred in 1900, a very unfavorable season.

The total precipitation for the season is equally misleading. For 1900 it was 1.04 inches greater than for 1901.

The average mean temperature for both the seasons of 1900 and 1901 were very nearly equal, and were about two degrees higher than the normal for the period of five years.

From the above considerations it can readily be seen that neither the annual nor seasonal precipitation, evaporation, or temperature gives any index to the amount of crop produced. These are all vital factors in determining whether crops shall be good or poor, but it is upon their distribution and inter-relation rather than upon their aggregate or average amounts that we will have to depend for an interpretation of the results given in Table XIII.

Beginning, then, with May, and comparing the years 1900 and 1901, Table XII, we will see that the evaporation for the month was 5.32 inches for 1900, while for 1901 it was only about half that, 2.70 inches. The precipitation was nearly an inch below the normal for 1901, but it was .57 inch greater than it was for 1900. The mean monthly temperature was three degrees higher for 1900 than for 1901.

The precipitation for June was 1.62 inches for 1900 and 4.51 inches for 1901, a difference of 2.89 inches. Another fact, which the table does not show, is that what precipitation did occur in 1900 was not well distributed, but came in the last few days of the month. The evaporation and mean monthly temperature did not differ materially for the two years, and were both above the normal for the period. This high temperature and consequent high evaporation was just what was needed in 1901, with its heavy rainfall, to produce a very vigorous growth, but was very disastrous in 1900, with only 1.62 inches of precipitation.

In July we find the conditions exactly reversed as to precipitation, 5.10 inches for 1900 and 1.66 for 1901, a difference of 3.44 inches. The evaporation for 1901 was also 2.57 inches higher than for 1900, due to the phenomenally high mean temperature of 76.2°, as compared with 68.2° for 1900. Had it not been for this very hot weather in 1901, which materially reduced the yields, the difference in the two years' crops would have been much more striking.

In August the precipitation was higher and the evaporation lower for 1900 than for 1901, while the temperature was higher for 1900.

Climatic conditions and the amounts of plant food and water required by growing plants are determined by laws of nature beyond the control of man, but the physical conditions of the soil and the adaptation of crops to each other and to their environment are to a great extent susceptible to modification by the adoption of intelligent, scientific methods of agriculture. It would be well, then, if some of the surplus energy that is now being devoted to vain speculations as to how the climatic conditions have changed, are changing, or may be changed, could be utilized in devising means for adapting our agricultural crops and methods to those conditions as they have been, are, and are likely to remain, for generations, at least.

As an example of a class of fallacies that catch the popular fancy and serve the purpose of certain interested parties, let us glance hastily at the theory that the climatic conditions of the state can be materially modified by forming lakes from artesian wells, thereby increasing the evaporation and presumably the precipitation.

We have found that the evaporation from an exposed surface of water, from the first of May until it freezes up in the fall, amounts, on an average for five years to, 18.5 inches. Let us add 2.5 inches more for what might occur during the remainder of the year, during nearly all of which time the surface of the water would be frozen over, and we will have 21 inches for the annual evaporation. But as the water would, if spread out in the form of lakes, have to occupy land upon which some kind of vegetation is now growing, and as this vegetation would transpire at least 6 inches of water per annum, the net gain by converting it into a lake would be 15 inches of evaporation.

Let us not be niggardly in the size of our lakes, but let us suppose that one-tenth of the entire surface of the state of South Dakota were converted into lakes. This would be only seven thousand, seven hundred and sixty-five square miles, and at the very moderate price of ten dollars per acre would cost only about fifty million dollars, and the interest at 4 per cent on the capital invested would be only two million dollars annually. It is true that some grasping old fogies who did not believe in undertaking to modify climatic conditions might not want to part with their rich bottom lands for the nominal sum of ten dollars per acre. But even if the land cost twenty dollars an acre that would be only one hundred million dollars, a mere bagatelle to any one who has started out to remodel the laws of nature.

It would require only about three thousand eight hundred and eighty-two artesian wells flowing one thousand gallons per minute for every minute of the year to keep up the evaporation at the rate we have estimated, after the lakes were once filled. It is true that the seepage might amount to as much or perhaps several times more than the evaporation, but that would simply require the supplying of a few thousand more artesian wells.

Of course there would be the selection of suitable sites for the lakes, the construction of dams, etc., mere engineering problems. But when we had secured our land and the wells, and got our lakes dammed and filled, we would be ready to reap the benefits.

Let us see what these benefits would be likely to be. It is not a difficult problem in mathematics. If fifteen inches of water evaporate from one-tenth of a given surface and it is all condensed and precipitated back evenly over the whole of that surface the precipitation would amount to one-tenth of fifteen, or to **one and one-half inches.** If any of this moisture should, by mistake, be carried over into Minnesota, Iowa, Nebraska, Wyoming, Montana or North Dakota before it was precipitated, we would have to reduce our one and one-half inches by just so much. It seems hardly likely, however, that a neighboring state would appropriate moisture that plainly belonged to us and had been produced at such a cost.

And yet there are some very bright men in South Dakota who think they think that the climatic conditions may be modified by the above methods.

The artesian water supply of this state is an important item among her resources, and one that should be utilized to the fullest extent. There are many places where low land could be converted into lakes or ponds, thereby adding not only to the beauty of the landscape and to the comfort and enjoyment of the people, but also increasing the value of the adjoining property. A start has already been made in this direction, and it is to be hoped that the good work may go on. There are many better reasons why it should than the hope that it may increase the rainfall.

Let us now consider how a fair yield of wheat was obtained in an unfavorable season by the adoption of rotations calculated to conserve the moisture and keep the soil in the proper physical condition.

TABLE XIII

Yields of Wheat and Oats in Different Rotations Compared for an Unfavorable and a Favorable Season

WHEAT AFTER:	No. of Plats	1900 Straw lbs.	1900 Grain bu.	1900 Ratio—1:	1901 Straw lbs.	1901 Grain bu.	1901 Ratio—1:
Fallow	4	2375	15.00	2.64	2848	15.66	3.03
Corn	6	2280	13.91	2.73	2958	17.35	2.84
Oats	4	1150	3.96	4.84	2558	16.75	2.54
Peas (fed)	1	1920	7.16	4.46	2660	18.16	2.44
Peas (cut)	2	1645	4.66	5.87	3020	14.66	3.43
Peas (plowed)	1	2290	14.83	2.57	2980	17.00	2.92
Potatoes	1	2300	13.33	2.88	2870	17.16	2.79
Vetch	1	1620	7.16	3.77	2580	15.33	2.80
Millet (cut)	3	1773	6.55	4.51	2770	16.33	2.83
Millet (fed)	1	1770	10.50	2.81	3020	16.33	3.08
Wheat	6	1415	3.60	6.63	2805	15.46	3.02
Averages		1867	9.15		2824	16.38	
OATS AFTER:							
Wheat	5	2046	12.63	5.06	2358	48.14	1.53
Corn	3	2280	28.75	2.48	2343	47.59	1.54
Averages		2163	20.69		2350	47.87	

Table XIII shows that the average yields of wheat from thirty plats was but 9.15 bushels per acre for 1900, while that from the same number of plats in the same rotations was 16.38 bushels for 1901.

The average yield of oats from eight plats was 20.69 bushels per acre for 1900, and 47.87 bushels for 1901. These figures fully bear out the conclusions arrived at from the examination of Table XII, that 1900 was a very unfavorable, and 1901 a fairly favorable season. But in spite of the very unfavorable conditions which prevailed in 1900, there were twelve plats out of the thirty that yielded on an average 14.27 bushels of wheat per acre. Four of these had been summer fallowed in 1899, six had raised a crop of corn, one a crop of potatoes, and one a crop of peas which had been plowed under. The other eighteen plats yielded only 6.23 bushels average. Of these four had raised oats in 1899, three peas, one vetch, four millet, and six wheat.

Of the eight plats of oats raised in 1900, the five that followed wheat yielded only 12.63 bushels per acre, while the three that followed corn produced 28.75 bushels per acre.

It will be seen that in the case of the wheat an increased yield of 8.04 bushels was obtained where the wheat followed summer fallow, corn, potatoes, or peas plowed under, while the advantage of raising oats after corn instead of after wheat was 16.12 bushels of oats. As a bushel of wheat is usually worth from three to four times as much as a bushel of oats, it would have paid better to have raised wheat after corn and oats after wheat in all the rotations.

The yields of both wheat and oats for 1901 were quite uniform and fairly good, although they were undoubtedly two or three bushels less than they should have been, judging from the growth of straw. This reduced yield was caused by the very hot weather in July. It will be noticed that the heaviest yields of grain were from plats having the lightest growth of straw and the lightest yields of grain were from plats having the heaviest straw, showing, what has frequently been observed, that where there is a very rank growth of straw the damage from hot winds is usually greater than where the growth has not been so luxuriant. There seems to have been no advantage from sowing wheat on summer fallow, or corn land. In fact the summer fallowed plats fell below the average by .72 bushels per acre.

While we should guard against forming too positive opinions upon an experience limited to six years, the evidence so far obtained certainly points very strongly toward the conclusion that, during years when there is a sufficient supply of moisture and a suitable temperature, properly distributed throughout the growing season, good yields of wheat may be obtained from our average prairie soils, where the crop is properly put in, without much regard to the kind of crop the land has raised the preceding season. But when the supply of moisture is deficient for the season, or is not properly distributed, a fair average crop can be produced, where a suitable rotation is practiced, while partial or total failure will result where wheat is sown after a crop that does not leave the soil in the proper physical condition. In short, it would seem that our soils after twenty years' continuous cropping have a sufficient supply of plant food to produce good crops, provided the physical condition of the soil is such that there is enough water to make this supply of food available to the plant.

We do not wish to be understood as discouraging the application of manure, for the plant food thus supplied may be stored up in the soil to guard against future drafts, and it is believed that their beneficial effects will become more apparent in time.

All the cuts in this Bulletin are from photographs taken in 1900, and are given to show the contrast between the crops grown under different systems of rotation.

EFFECTS OF THE FREQUENCY OF CROPPING WITH WHEAT

In Table XIV we have grouped the rotations according to the number of years intervening between the wheat crops, in order to learn if possible whether the frequency of cropping to wheat has any effect upon the yield. We have five groups, in which the wheat crop occurs every five, four, three two and one years, respectively. We find that where wheat occurs only once in five years the average yield has been 15.27 bushels; that where it occurs every two years the average yield has been nearly the same, 15.33 bushels per acre. And that the yields in the other three groups differ from each other by less than one bushel per acre, and are considerably less than for the two and five year periods.

This evidence would seem to indicate that, so far as our experience has extended, there are other influences governing the yields, to such an extent that whatever effect the frequency of cropping to wheat may have upon the yields of wheat, is entirely obscured. As before stated, the most potent influence governing the yield is the effect of the immediately preceding crop. This failure to detect any relation between the length of the interval between wheat crops and the yields only strengthens our former conclusions, that the wheat yields depend almost entirely upon the kind of crop that immediately precedes the wheat crop.

TABLE XIV

Table Showing the Effects of Frequency of Cropping With Wheat

Rotation No.	Straw lbs.	Grain bu.	Lbs. Straw for 1 lb. Grain
WHEAT ONCE IN FIVE YEARS			
1—Flax, barley, millet, wheat, corn	2498	15.25	2.73
5—Wheat, oats, corn, flax, millet (fed)	2450	15.29	2.67
Averages	2474	15.27	2.70
WHEAT ONCE IN FOUR YEARS			
8—Wheat, corn, oats, millet	2068	13.04	2.64
WHEAT ONCE IN THREE YEARS			
2-2—Wheat-1, oats, peas (fed), wheat-2, roots	2228	15.16	2.45
3-1—Oats, wheat-1, fallow, wheat-2, corn	2103	13.04	2.69
4-2—Wheat-1, barley, peas (plowed), wheat-2	2603	16.12	2.69
6-2—Wheat-1, barley, peas (cut), corn, wheat-2, corn (fed)	2513	12.25	3.42
10—Wheat, corn, oats	1832	10.90	2.79
11—Oats, fallow, wheat	2560	18.66	2.28
12—Barley, millet, wheat	1960	13.40	2.43
13—Barley, peas (cut), wheat	2148	12.36	2.89
Averages	2243	13.94	2.70
WHEAT ONCE IN TWO YEARS			
2-1—Wheat-1, oats, peas (fed), wheat-2, roots	2315	16.41	2.35
3-2—Oats, wheat-1, fallow, wheat-2, corn	2378	15.40	2.57
4-1—Wheat-1, barley, peas (plowed), wheat-2, corn	2498	17.70	2.35
6-1—Wheat-1, barley, peas (cut), wheat-2, corn (fed)	2392	16.10	2.47
7-1—Wheat-1, corn, wheat-2, oats	1825	11.46	2.65
7-2—Wheat-1, corn, wheat-2, oats	2147	14.50	2.47
9-1—Wheat, corn (manured), wheat-2, oats	1695	11.79	2.40
9-2—Wheat, corn (manured), wheat-2, oats	2563	16.25	2.62
14-1—Wheat-1, wheat-2, fallow	2254	15.10	2.48
15-1—Wheat-1, wheat-2, corn	2608	14.53	2.99
16—Wheat, fallow	2610	17.16	2.53
17—Wheat, corn	2720	18.60	2.49
18—Wheat, vetch	2196	14.33	2.50
Averages	2323	15.33	2.53
WHEAT CONTINUOUSLY			
14-2—Wheat-1, wheat-2, fallow	1982	12.20	2.48
15-2—Wheat-1, wheat-2, corn	2490	12.40	3.35
19—Wheat continuously, no manure	2058	14.11	2.43
20—Wheat continuously, manured every five years	1950	13.80	2.35
21—Wheat continuously, manured every three years	2424	12.40	3.25
22—Wheat continuously, manured every year	2700	14.27	3.15
Averages	2268	13.20	2.83

EXPERIMENTS IN THE APPLICATION OF MANURE TO WHEAT

In the fall of 1896 twenty-four one-tenth acre plats were set aside for the experiments in the application of manure to wheats, as shown in Table XV. These plats had raised corn, sorghum or other cultivated crops during the season of 1896, except as otherwise noted in the table, and were therefore in very good physical condition for the wheat crop of 1897. Previous to 1896 they had all been treated about alike. They had been under cultivation for at least fifteen years and, so far as is known, had not been manured. The soil was of a very uniform character throughout. In the spring of 1897 and 1898 the wheat was drilled in crosswise of the plats and the alley-ways were cut out and the plats each trimmed to exact dimensions after the wheat was well up. Each plat was harvested and threshed separately.

The following table gives the treatment of each plat in 1897 and the yields for 1897 and 1898. The plats were again sown to wheat in 1899, but after a very careful examination of the standing grain at harvest time it was decided that, from all appearances, the yields of all the plats would be so near alike that it would not pay to harvest them separately. No manure was applied to any of the plats in 1898 or 1899, and the treatment given then was exactly the same for all the plats, so that it is fair to assume that whatever difference in yield was obtained in 1898 was due to the manuring of 1897.

On April 24th, 1897, all the plats were thoroughly dragged, and where coarse manure had been applied it was disced in, and the coarse straw raked and burned. When, in this way, all the plats had been put in good condition, they were sowed crosswise of the plats with a Van Brunt seeder set at one and one-fourth bushels per acre. The wheat was obtained from Wm. Caldwell of Brookings, and is called Okanagan Valley Velvet Chaff, but is probably somewhat mixed. It had been raised in this vicinity for seven years. It was clean and of fine quality. After sowing, the plats were dragged over once, lengthwise, in order to cover the seed on the manured plats.

In 1898 the seeding was done upon April 12th, in like manner as in 1897, using the wheat raised the previous year for seed.

Table XV—Effects of Manuring Wheat

	Yields per Acre			
	1897		1898	
	Straw, lbs.	Grain, bu.	Straw, lbs.	Grain, bu.
Plat No. 17 had an application of 5,650 lbs. of coarse, fresh horse manure on September 20th, plowed 8 inches deep on the 21st	2505	18.40	2120	17.16
Plat No. 18 had an application of 6,400 lbs. of well rotted cow manure on the 20th, plowed under 8 inches deep on the same day	3805	21.00	1965	18.00
Plat No. 19 was plowed 8 inches deep on September 20th and on the 21st 5,740 lbs. of long, coarse, fresh horse manure was spread on the surface	3475	21.50	2190	21.41
Plat No. 20 was plowed 8 inches deep September 20th, and on the 21st 9,600 lbs. of fine, well rotted cow manure was spread upon the surface	3430	19.50	2050	18.33
Plat No. 21 was plowed 8 inches deep September 20th. Horse manure was drawn from the stable during winter and applied to the surface	2750	19.17	1745	18.43
Plat No. 22 was plowed 8 inches deep September 20th. Cow manure was drawn from the stable and applied to the surface; 2 loads, 1 cord	2820	18.00	1450	16.16
Plat No. 23 had horse manure drawn direct from the stables and applied during the winter and plowed under in the spring; 3 loads, 1⅜ cords	2980	17.50	1450	16.16
Plat No. 24, same as 23, except that cow manure was used; 2 loads, 1 cord	2670	20.00	1870	20.50
Plat No. 25 had fine mixed manure applied in spring and disced in; 6,385 lbs., 2 loads	3305	20.25	3240	23.83
Plat No. 26 was plowed 8 inches deep September 20th. Fine manure was applied as a mulch after sowing in the spring; 6,000 lbs., April 27th	2940	15.00	2240	22.66
Plat No. 27 was summer fallowed (plowed in April and July 1896). It was plowed in the spring and had fine manure applied as a mulch after sowing grain; 5,000 lbs., 2 loads	2650	11.66	1945	20.91
Plat No. 28 was summer fallowed (plowed in April, July and September), and sown in spring without manure	2500	14.57	1600	16.25
Plat No. 29 is the same as 28, except that it was not plowed in the fall, but in the spring	2522	14.07	1350	18.42
Plat No. 30 same as 27, except that coarse manure was used; 4,750 lbs., 2 loads	2390	8.83	1945	20.83
Plat No. 31 was plowed September 20th, 8 inches deep, and coarse manure applied as a mulch after sowing in the spring; 4,000 lbs., 2 loads	2260	9.83	2700	20.48
Plat No. 32, 5,025 lbs. fine, well rotted cow manure was applied September 23d, and was immediately disced in about 4 inches deep	2400	15.00	2275	22.25
Plat No. 33, cow manure was applied in the spring and plowed under; 6,180 lbs., 2 loads	2420	15.50	......	......
Plat No. 34, horse manure was applied in spring and plowed under; 5,335 lbs., 2 loads	2550	18.33	1860	19.41
Plat No. 35, fine mixed manure was applied in spring and plowed under; 6,775 lbs., 2 loads	2490	17.33	1925	18.75
Plat No. 36 was disced in the spring and no manure applied	2280	17.83	1460	18.16
Plat No. 37 was plowed September 20th, 8 inches deep. Fine manure was applied in the spring and dragged in; 7,535 lbs.	2670	17.16	1875	18.33
Plat No. 38 same as 37, except that coarse manure was applied	2810	20.66	2025	19.58
Plat No. 39 was plowed 8 inches deep September 20th. No manure was applied	2565	18.08	1515	16.83
Plat No. 40 was plowed in the spring and no manure applied	2150	14.16	1410	14.83
General averages	2722	16.80	1922	19.05
Average for manured plats	2780	17.12	2017	19.57
Average for unmanured plats	2434	15.22	1469	16.58
Average gain from manuring	346	1.90	548	2.99
Average for mulched plats	2558	11.33	2207	21.22

The season of 1897 was a rather peculiar one, and to this cause is no doubt due some of the rather unlooked for results obtained from our experiments. The mean temperature for May was 56.10°, being slightly above the normal for that month. The total precipitation for the month was .83 of an inch, which is 1.89 inches below the normal. The temperature fell to 23° on the 24th of the month, a severe frost resulting. The mean temperature for June was 63.06°, which is about two degrees below normal. The precipitation was 3.86 inches, which is about one-half inch above normal.

The wheat suffered some during May from a lack of moisture, and the damage from frosts was considerable on some plats. The conditions for June were more favorable, although the fore part of the month was too cold for the best results, the thermometer registering 28° on the 6th and 26° on the 7th. Those plats that had received treatment that would tend to warm the soil produced better results than those that had been treated in such a manner as to keep it cool and moist. These results are probably just the opposite of what could reasonably be expected in an average year in this state. It is believed, however, that some valuable lessons may be learned from the results obtained. We therefore give a portion of the field notes which were taken during the season of 1897:

May 5—The plats were all gone over. There was no apparent difference in them, except that No. 39 was a little the largest and appeared much greener than the rest; while No. 40 showed the least growth. This is probably accounted for by the depth of seeding. No. 39 was fall plowed and the soil was quite firm; No. 40, being spring plowed, was loose and the grain was therefore put in deeper.

May 7—Examined all the plats today, and there is no apparent difference. The surface of the ground is very dry.

May 14—The above mentioned dryness has been overcome,

.39 of an inch of rain having fallen during the past week. The weather has been exceptionally cool and all plats are thriving. No apparent difference in color or size of wheat.

May 24—Last night there was a heavy frost. The thermometer registered 23°. The wheat on nearly all plats was touched, some so slightly as not to seriously injure it, while others were badly bitten.

Nos. 17 and 18 were somewhat blackened.

No. 19 slightly frosted.

No. 20 worse than 17 and 18.

Nos. 21 and 22 not so bad as 17 and 18.

No. 25 not touched.

Nos. 26 and 27 badly bitten.

Nos. 28 and 29 barely touched.

Nos. 30 and 31 badly bitten.

No. 32 barely touched.

Nos. 33, 34, 35 worse than No. 32.

Nos. 36, 37, 38, 39, 40 slightly touched.

Nos. 19, 25, 32 were least affected.'

On these the manure, fine on Nos. 25 and 32, and coarse on No. 19, was applied in the fall and worked into the soil, thereby, undoubtedly, causing the ground to be warmer. Nos. 26, 27, 30, 31 were the worst bitten. On these the manure was applied after sowing. This mulch, undoubtedly, kept the ground moist and cold, thus increasing the damage done by the frost.

June 5—All wheat looking well. Has recovered from the freeze. Plats No. 28 and No. 29 are very fine, but No. 32 seemed yet to be the best. Average length of leaf 7 inches, and average height 4 inches.

July 2—All wheat is well jointed, and on No. 25 a few heads were seen. The standing height is 26 inches. No. 20 stood 25 inches. No. 25 and No. 27 and several others are very fine, but No. 32 is still a little in advance of them all. No. 36 seems to be the poorest, standing height 19 inches.

July 5—All plats being rusted, apparently the same, but as yet not badly. It cannot be due to the manuring.

July 12—The rust is increasing, but its advance seems the same on all plats. In no case was the rust found on the stem.

July 21—The wheat is somewhat blighted.

July 26—The blight on the wheat carefully noted. Where any was found blighted, all the stalks having come from the same kernel were found to be affected. These heads were found by Professor Saunders to be affected by an imperfect fungus, Macrosporium Sp. The manured plats seemed to be worse than the unmanured. Nos. 19, 21, 26, 32 seemed a little worse than the others. Merely the tips of many heads are light colored and without kernels. This is probably caused by the hot, dry weather.

August 9—All of the wheat except Plats Nos. 26, 27, 30 and 31 were harvested today. Three plats were very ripe and in the following order: Nos. 17, 18 and 38; the rest of them about the same and all ripe enough.

August 11—Plats Nos. 26, 27, 30, 31 were harvested today. They were not as ripe as the other plats were on the 9th, but would probably not get any better. They were not so thick as the other plats.

An examination of the above notes and the foregoing table will show that the yields were very materially affected by the physical condition of the soil, produced by the application of manure, and, in some instances, the bad physical effects more than counterbalanced the beneficial fertilizing effect of the application.

Summing up the results of the whole experiment, we will see that the advantages gained from the application of manure were sufficient to considerably more than pay for the labor and expense incurred. The average yield of all manured plats have been increased for the year 1897 by 1.9 bushels, and for 1898 by 2.99 bushels. Had it not been for the bad effects produced by mulching in 1897 the advantages would have been considerably greater. It will be noticed that the mulched plats, Nos. 26, 27, 30 and 31, which gave the lowest yields in 1897, gave exceptionally good yields in 1898, thus bearing out the theory that the bad results in 1897 were due entirely to the physical effects of the application.

The farmer should fully understand that while the application of barnyard manure to the soil is certain to have a beneficial effect by adding to the store of plant food, its effects may not be apparent in the results of the first crop after the application, and that the immediate mechanical or physical effects upon the soil may be either beneficial or detrimental, depending upon the character of the soil, the kind of manure, the time and method of application, the nature of the crop and the character of the season as to moisture and temperature.

The soil of the farm should be considered a bank in which the surplus resources of the farm, in the form of plant food, should be deposited with the understanding that this surplus cannot be withdrawn at once, but is to remain until such time as the conditions are favorable for its utilization. With our light rainfall and retentive soil the danger of loss from leaching is very slight.

From our experience and observation we believe we are warranted in recommending as the surest method of guarding against the possible bad physical effects of the application of the manure, that it be applied to land intended for corn instead of wheat; that it be hauled direct from the stable, during the late fall, winter and spring, and plowed under in the spring. The corn will be likely to be benefited, and the wheat crop that should follow the corn will probably be improved as much, or more, than it would if the manure were applied direct to that crop.